POULTRY PRODUCTION

Leslie E. Card

POULTRY PRODUCTION

FORMERLY BY LIPPINCOTT AND CARD

BY

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PREFACE TO THE EIGHTH EDITION

This eighth edition of Poultry Production has been prepared with one main objective—to make it useful to persons who want to understand both the science and the practice of poultry and egg production. Each succeeding revision of the book has seen increasing emphasis placed on the results of research, and on the interpretation of new findings as they apply to poultry practice. This approach is especially important today because of the many technological developments in the industry.

It would have been gratifying to the author, as well as to the many research workers whose published papers have been consulted, to include a list of references at the end of each chapter in recognition of the valuable contributions which these workers have made to our knowledge of the hen and her products. They have been omitted, reluctantly, as one means of keeping the price of the book at a reasonable figure.

Grateful acknowledgement is made to certain individuals who helped in various ways. Dr. H. J. Sloan of the University of Minnesota and Dr. H. M. Scott of the University of Illinois reviewed the entire text and made numerous helpful suggestions. Dr. George E. Cottral of the Regional Poultry Research Laboratory at East Lansing, Michigan, gave valuable assistance on technical points in connection with the revision of Chapter 12.

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I am deeply appreciative of the courtesies extended by various organizations and individuals in permitting the use of illustrative material. Dr. Bradley M. Patten and The Blakiston Company very kindly permitted the use of four illustrations from the fourth edition of "Early Embryology of the Chick." The Company of Biologists, Ltd., Cambridge, England, granted permission to reproduce from the *Journal of Experimental Biology* the illustrations used in Plate II.

The kodachrome used for the cover design was loaned by the Pennsylvania Agricultural Extension Service through the courtesy of Dr. George F. Johnson. Several other illustrations were made available through the courtesy of *Poultry Tribune*, *U. S. Egg and Poultry Magazine*, and *American Poultry Journal*. Credit has been indicated in all such cases.

Finally, I wish to acknowledge my indebtedness to Dr. W. A. Lippincott, author of the first four editions of Poultry Production. Very little of his actual writing remains, but this is only because advances in poultry science and practice have made it necessary to rewrite sections or entire chapters from time to time. The organization of the book is still substantially the same, with the addition of a final chapter on the business of poultry keeping.

L. E. C.

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A PERSONAL NOTE TO STUDENTS

Textbooks are traditionally descriptive, factual and conservative, and they too often make dry reading. The author is expected to write as if talking *about* his subject rather than *to* his readers. This results in a formal style which does not help the "meeting of minds" between author and reader.

I have gone along with precedent in the fourteen chapters which follow, but because I believe that you who study this book are entitled to something more than this, and because many of you are presumably advanced undergraduates in Land-Grant Colleges of Agriculture, I want to tell you why I have stressed certain subjects and have treated others very briefly. I also want to give you some idea of the opportunities which may be open to you when you graduate.

During twenty-five years of teaching undergraduate students at the University of Illinois I have observed that certain subject matter topics, year after year, were difficult for students to grasp. Some of these topics I have tried to clarify in this revision by a new, or at least a different, approach. Others have been expanded to include more background material.

Those of you who have elected a course in poultry husbandry—yes, even those who are taking poultry as a required course—are fortunate in that this, like most subjects in agriculture, deals with living things. The pertinent information is constantly changing—it is not static. That is why several chapters in this book have had to be completely rewritten for this eighth edition.

Up to the turn of the century most poultry books dealt with breeds and varieties and with the art of feeding and management. There was no science of poultry production, nor was there a poultry industry as we know it today. Mammoth incubators and the coal stove brooder had not been invented. There was no information about the inheritance of egg production. Almost nothing was known about vitamin requirements of chickens, or about the efficiency with which chickens could transform feed into poultry meat. No one

was studying the cost of egg production, and there were no egg and poultry processing plants.

All this has changed. We now know far more about the genetics of the fowl and about the nutritional requirements of the growing chick than is known about any other animal species of economic importance. Conversely, breed and variety have become of minor importance except as they affect economic production and returns. Very few poultrymen today are concerned about the number of points on a single comb, about a few black feathers on a Barred Plymouth Rock, about whether a White Plymouth Rock is "pure bred," or about a little down between the toes of baby chicks. But they are very much concerned about how fast the feathers grow, how well they cover the chicken, whether gains are rapid and economical, and whether the production index of a flock is 200 or more eggs.

With these things in mind, this eighth edition of Poultry Production has been substantially changed in several ways:

1. The chapter on breeds and varieties has been dropped.
2. The section on endocrines and their functions has been expanded.
3. Poultry breeding and improvement have been discussed in terms of the interaction of heredity and environment and the relation of this concept to selection methods.
4. The subject of poultry housing has been developed as a problem in biology and engineering.
5. A discussion of the individual amino acids and their place in poultry feeding has been added.
6. There has been brought into the final chapter a discussion of the concept of marginal production and marginal revenue as factors in profitable poultry production.

If this seems confusing and a bit difficult, it is only because poultry science has been making rapid advancement. You are to be congratulated on having the opportunity to participate in that advancement. And as you become familiar with the vast literature bearing on the whole subject of poultry and egg production, you will realize that neither interpreting nor condensing this material into a book to be covered in a single quarter or semester has been an easy task. I have tried to do both of these things in such a way as not to mislead any reader. How well I have succeeded, only you and your instructor can judge.

Every poultry student should be familiar with sources of additional information on special topics, as well as with sources of new material currently appearing in original articles. The books listed on page 31, together with the journal *Poultry Science*, will make an adequate working library for most students. Specialists will want some other books, and will need to follow several other journals.

Opportunities for College Graduates.—Opportunities in the poultry business are closely related to the food needs of the population.

Psychologists often refer to human wants and desires, but food is a need that is important to most people three times a day. The simple fact that births in the United States are occurring at the rate of one about every ten seconds furnishes ample evidence of the continuing opportunity which exists in all branches of the food industry. The poultry business benefits because poultry and eggs are important items of human food.

Because of increased efficiency in agricultural production, and because of the increasing demand for many new kinds of goods and services, the long-time trend in population shifts has been away from farms into cities and towns. As long as this continues, it means that numerically there will be more opportunities for employment in the cities and towns than on farms, and many agricultural college graduates must look in that direction because they cannot go direct to the farm.

Many employers in both large and small businesses related to agriculture prefer to hire college-trained men who have a farm background. The reasons are simple. A college graduate is favored because he had the energy and vision to spend four years in study and preparation for a job. A farm background usually means that he is willing to work and that he knows how; that he is resourceful, and can improvise when necessary, to meet a new situation. It means also, especially if it included 4-H or F. F. A. experience, a character background which makes for good citizenship—a most valuable asset in any business. Of course along with these qualities, the college graduate is expected to know something about poultry management, poultry nutrition, poultry genetics, or poultry and egg marketing, as the case may be.

Some of the best job opportunities are in sales and service with feed manufacturers, poultry equipment and supply firms, hatcheries, and specialty companies manufacturing or dealing in products which are needed by various branches of the poultry industry. There are numerous opportunities in the processing field because of the tremendous volume of poultry and eggs handled every year. In choosing a job in any one of these fields, it is well to find out about the local reputation of the particular business firm or local branch. Is the local manager thought well of in the community? Are the present employees enthusiastic about their work?

There are also a great many jobs which call for some knowledge of poultry as part of a broad agricultural training. Assistant county agents, teachers of vocational agriculture, and service men with farm bureau supply companies are examples.

Becoming a Poultryman.—The poultry business is safer and saner today than it was even ten years ago. There are fewer complications, because of more and better knowledge about feeding, breeding and management. As evidence of this, large production units are be-

coming the rule rather than the exception in many parts of the country.

If you want to get into the poultry business for yourself, there are several possibilities. You can follow the sound and time-honored procedure of going to work for someone else while gaining experience and accumulating sufficient capital to start your own business. In some of the commercial broiler areas you can, with even limited experience, get started on a basis in which the financial risk is largely assumed by a feed dealer, hatcheryman or processor who advances the money for chicks, feed, and perhaps for equipment. The operator supplies all labor for a proportionate share in the returns.

Acquiring a hatchery with limited capital is more difficult. There are fewer opportunities for new hatcheries today than there were twenty years ago, and a prospective owner may have to purchase an entire plant and good will. You might, however, be so fortunate as to find an owner who is about ready to retire and who would take you in as a partner, giving you the opportunity of buying the business as you can.

You might make similar arrangements for the purchase of a commercial egg farm. Or you might have a chance to take over the managership of such a farm on a salary and profit-sharing basis, with the understanding that an opportunity to purchase would be given later. Whatever the arrangement, you as the new operator must remember that it takes time, energy and money to establish a successful business. You must therefore be willing to put in several years of your own time and energy if you are to develop a new business or acquire one that is already established.

Whatever your future objective—whether it is to become identified with the four-billion-dollar poultry industry or simply to be a better-informed consumer of its products—I trust that your study of this book may be both interesting and profitable. If you gain nothing else, you should have a better conception of the magnitude and significance of the poultry industry and an understanding of why so many men are proud to be a part of it.

L. E. Card

7-SEP 1956
T. KALLUPATTI

POULTRY PRODUCTION

CHAPTER 1

THE POULTRY INDUSTRY

Poultry production exists as an industry because poultry and eggs are prized as human food. Chickens are often raised as a hobby, feathers are put to many different uses, and great quantities of eggs are used in the preparation of therapeutic vaccines, but all these things are distinctly secondary to the use of poultry and eggs as human food. Furthermore, the business of producing, processing, transporting, storing, financing, and serving food gives employment to more persons in this country than do all other businesses combined. Poultry meat and eggs are important commodities in the food business.

Poultry and egg production is no longer a minor farm enterprise, even though there are still enough flocks of fewer than 200 hens each to produce about half of all the eggs and farm-raised chickens each year. The business has rapidly become technological, and there is every indication that this trend will continue. Of the total gross farm income in the United States in 1949, 11 per cent was derived from poultry products. For nine eastern states it was more than double this figure, and in Delaware it was 69 per cent. (See Table 1.)

Table 1.—The Rank of the First Ten States, and of Four Regions, in Percentage of Total Farm Income Derived from Poultry and Eggs, 1949. (Data from U. S. Department of Agriculture.)

Rank	*State*	*Per cent of total farm income derived from poultry products*
1	Delaware	69
2	New Hampshire	42
3	New Jersey	35
4	Massachusetts	33
5	Connecticut	29
6	Maryland	28
7	Rhode Island	28
8	Pennsylvania	25
9	West Virginia	25
10	Maine	21
Northeastern States (11)		25
North Central States (12)		10
Southeastern States (14)		9
Western States (11)		8
United States		11.5

7-SEP 1956

Changes in population can have significant effects on the poultry business. In 1930 California shipped more eggs to New York, Chicago and Philadelphia than it did to either of its own markets, San Francisco and Los Angeles. Today, with the rapidly expanding population on the west coast, it sends almost no eggs east. Instead, eggs are shipped into California from Minnesota, Iowa, Nebraska and Kansas, as well as from Utah. Considering the country as a whole, the large centers of population are mostly east of the Mississippi River, while much of the excess poultry and egg production is in the Mississippi Valley. Poultry and eggs therefore move east to the large central markets.

GROWTH OF THE INDUSTRY

The poultry industry has shown a tremendous growth in the last twenty-five years, largely because of a complete and fundamental change in viewpoint. Instead of keeping chickens as a hobby or a sideline, for pleasure and some incidental profit, hundreds of thousands of flock owners have come to look upon the poultry enterprise

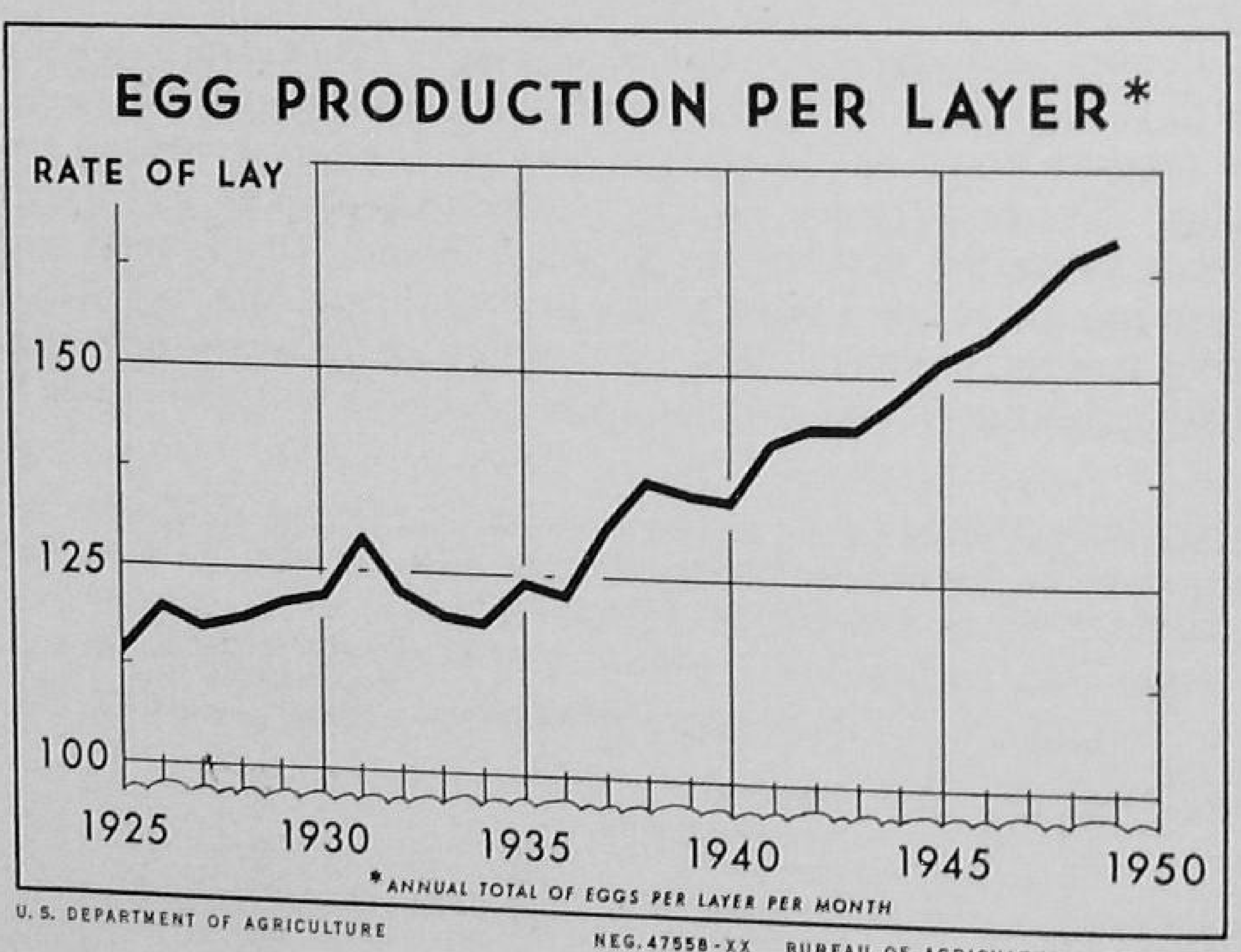


FIG. 1.—Annual rate of lay has been increasing, except for brief periods, since 1925.

on their farms as an economic unit, a means of livelihood, a source of income by which to raise and educate a family and acquire a certain degree of economic independence. Instead of keeping chickens, they have made the chickens keep them.

In January, 1925, the U. S. Department of Agriculture began reporting the number of eggs produced each month for each 100 layers on farms. For twelve years the annual total ranged a little above or below 120 eggs for each hen and pullet in farm flocks. Then in 1937 there began a steady and almost continuous rise in production which brought the 1950 figure to 167, almost 40 per cent above the average for the first twelve years of record.

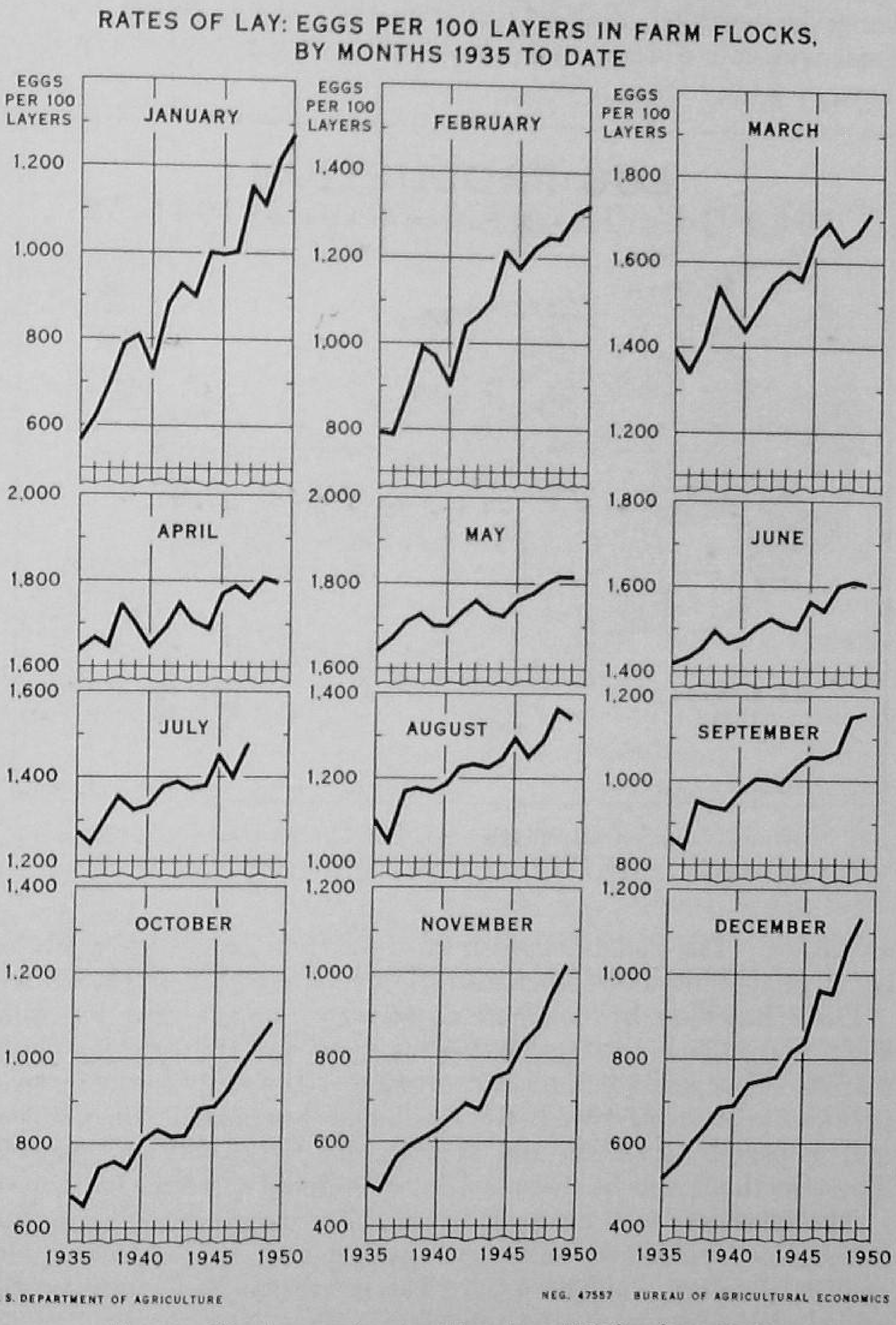


FIG. 2.—The increase in rate of lay since 1935 has been most marked in October, November, December and January.

There are several reasons for this spectacular rise, and the increased production has, in turn, been responsible for many other marked changes in the poultry industry. In 1928, about 43 per cent of the chickens raised on farms were hatched under hens, and only 23 per cent were bought as baby chicks. By 1938, 66 per cent of the chickens raised were purchased as baby chicks. In 1950, this figure had risen to 91 per cent and, in addition, commercial hatcheries produced over 600 million chicks for the commercial broiler trade. This change has enabled producers to start their chicks earlier than is usually possible when all must be hatched on the farm where they

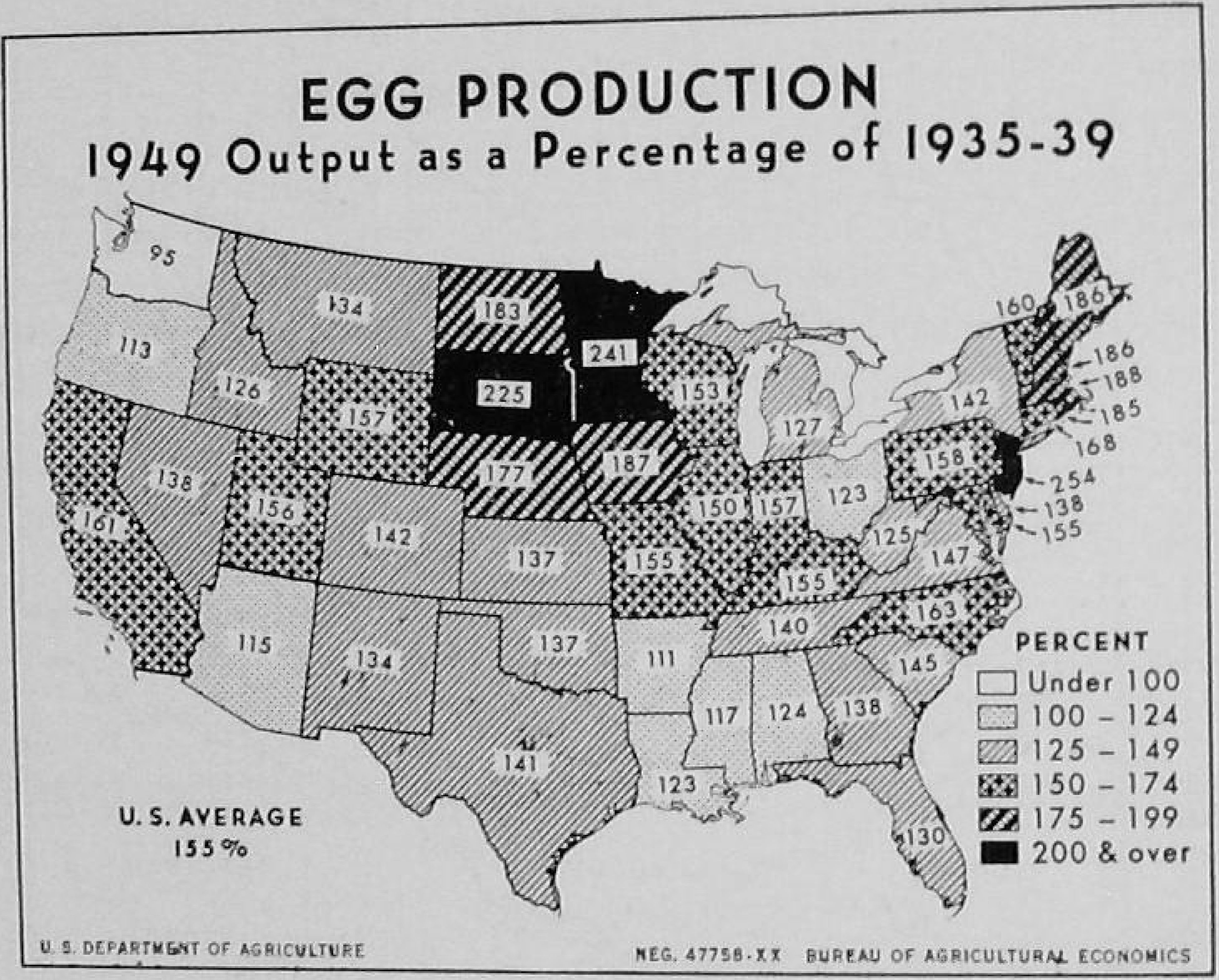


FIG. 3.—Total egg production has increased much more in some states than in others.

are grown. The pullets raised from these early chicks are ready to lay in September or October instead of in November or December.

Early hatching by commercial operators meant that breeding flocks had to be in production well in advance of the usual hatching season. This was accomplished in part by the early hatching of a previous year, in part by better feeding and management methods, and in part by selection and breeding for the ability to lay well. These methods will be discussed in some detail in later chapters.

The increase of 40 per cent in annual production per layer has been gained chiefly by increased performance in November, December, January and February. The increase in these four months added about 28 eggs to the annual average so that for the 1949–50

laying year the cumulative total for November through June was greater than the entire year's production in 1924–25. (See Table 2.)

Prior to 1937, egg consumption per person in the United States was about 300 eggs a year. With increased production from farm hens, more eggs of better average quality became available, and the American public responded by increasing consumption till it is now about 400 per person per year. According to data reported by the U. S. Department of Agriculture, consumption of eggs in 1949 was up 27 per cent over the years 1935 to 1939. Consumption of all meats was up 14 per cent, fluid milk and cream 13 per cent, and fruits 2 per cent. Consumption of vegetables, grain products and fats was down.

TABLE 2.—EGG PRODUCTION PER LAYER, BY MONTHS, WITH CUMULATIVE TOTALS, FOR INDICATED YEARS, 1925-1950. (DATA FROM U. S. DEPARTMENT OF AGRICULTURE.)

Month	1924–25		1929–30		1934–35		1939–40		1944–45		1949–50	
November	3.4*		4.1		4.7		6.1		7.5		10.2	
December	3.9*	(7.5)	4.1	(8.2)	4.7	(9.4)	6.8	(12.9)	8.2	(15.7)	11.3	(21.5)
January	4.1	(11.6)	5.3	(13.5)	5.7	(15.1)	7.3	(20.2)	10.0	(25.7)	12.8	(34.3)
February	7.2	(18.8)	8.7	(22.2)	7.9	(23.0)	9.0	(29.2)	11.7	(37.4)	13.2	(47.5)
March	13.5	(32.3)	15.1	(37.3)	14.0	(37.0)	14.4	(43.6)	16.6	(54.0)	16.9	(64.4)
April	15.8	(48.1)	16.6	(53.9)	16.4	(53.4)	16.5	(60.1)	17.7	(71.7)	17.6	(82.0)
May	15.6	(63.7)	16.4	(70.3)	16.4	(69.8)	17.0	(77.1)	17.6	(89.3)	18.1	(100.1)
June	13.2	(76.9)	13.9	(84.2)	14.1	(83.9)	14.8	(91.9)	15.6	(104.9)	16.2	(116.3)
July	11.9	(88.8)	12.3	(96.5)	12.7	(96.6)	13.3	(105.2)	14.5	(119.4)	15.2	(131.5)
August	10.4	(99.2)	10.5	(107.0)	11.0	(107.6)	11.9	(117.1)	13.0	(132.4)	13.9	(145.4)
September	8.4	(107.6)	8.4	(115.4)	8.7	(116.3)	9.8	(126.9)	10.6	(143.0)	11.9	(157.3)
October	5.9	(113.5)	6.2	(121.6)	6.7	(123.0)	8.0	(134.9)	8.8	(151.8)	11.1	(168.4)

* Estimated as being the same as for corresponding months in 1925.

Another reason for increased egg consumption is that with increased production, fresh eggs are available to more people throughout the year. Even as recently as 1939–40 (see Table 2), there were six months of the year in which the average number of eggs per hen was fewer than 10, but by 1949–50 the average rate of lay was 10 eggs or better in all twelve months. This leveling out of production has tended to level out the price. The peak monthly price is much closer to the springtime average price than it was back in the period from 1925 to 1935. Because of more uniform egg production, fewer shell eggs go into storage. Peak holdings in recent years have been about half as large as formerly.

Coincidental with the nation-wide increase in average egg production was an even more spectacular rise in the production of commercial broilers. Broilers were being grown on a fairly extensive scale in the Delmarva section (adjoining counties in Delaware, Mary-

land and Virginia) in the late twenties. In 1934, when the U. S. Department of Agriculture began reporting commercial broilers separately from farm-raised chickens, the U. S. total was 34 million, about 4 per cent of the total chicken meat supply. Broiler production increased, by successive 5-year intervals, to 106 million in 1939, 265 million in 1944, and 501 million in 1949. A further increase of 23 per cent in 1950 brought the total to 616 million, or 43 per cent of the total chicken meat supply when figured on a weight basis.

This rapid expansion has been possible largely because of the nation-wide increase in average egg production. Since fewer hens were needed to produce the nation's eggs, fewer farm-raised chickens

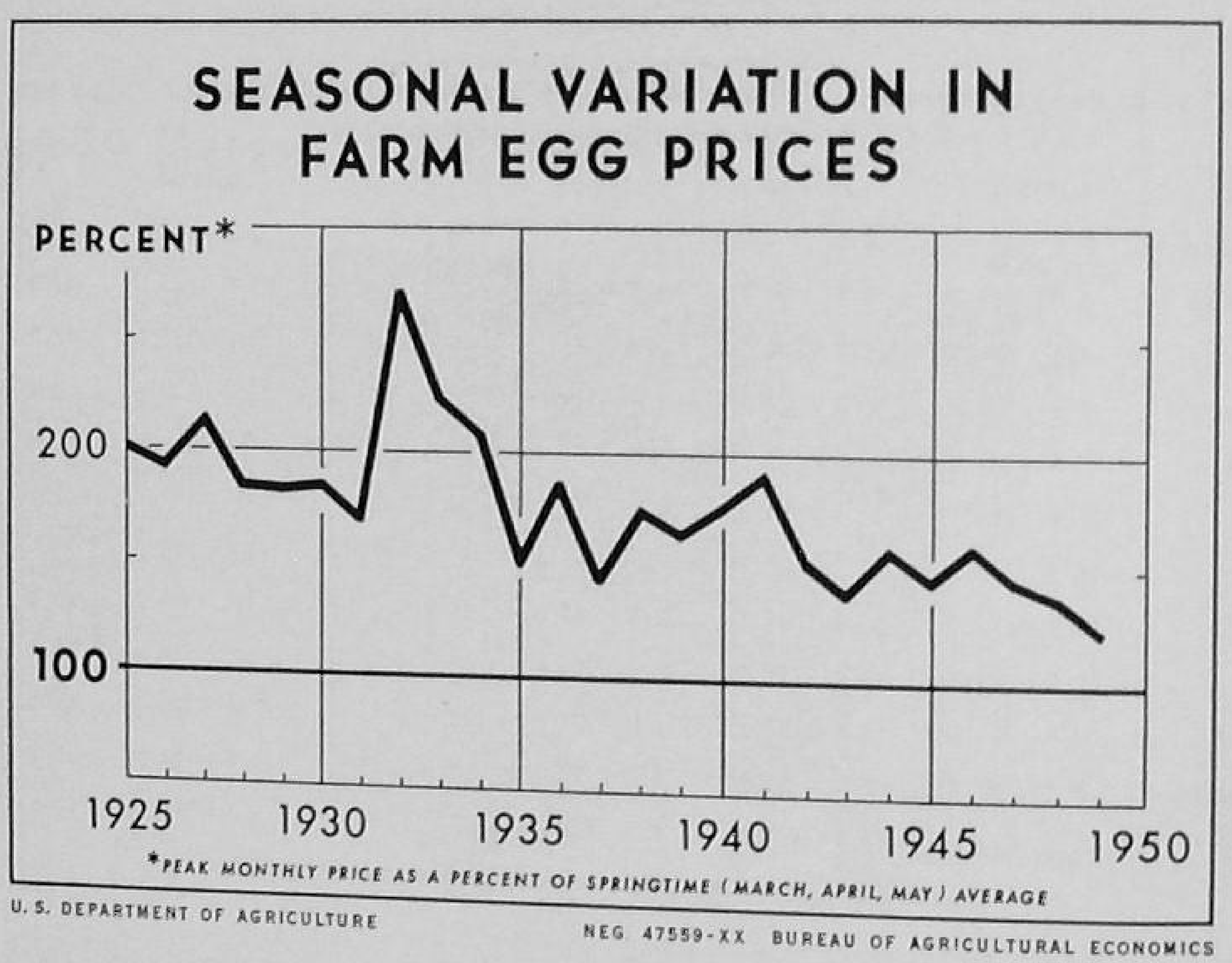


FIG. 4.—The peak monthly farm price of eggs has been declining with reference to the springtime average.

were grown relative to human food needs, and about one-third of the crop consisted of pullets instead of straight-run chicks of both sexes. This left a gap to be filled by commercial broilers.

But production alone was not enough. New methods of processing, packaging and distribution, especially the retailing of fresh-killed and frozen ready-to-cook broilers, and the fact that such broilers were widely available at a favorable price when compared with other meats, favored an increase in consumption. During the five years from 1935 through 1939, chicken meat consumption averaged 17.9 pounds per person per year. Ten years later, during 1945–1949, it had risen to 25.2 pounds, an increase of 41 per cent. Most of this increase was broilers.

Since broiler production has been concentrated in new areas, as contrasted with the production of farm-raised chickens, many new processing plants have been built in the broiler areas, even when other well-equipped plants in areas of farm production had to be shut down and devoted to other purposes because of an inadequate local volume of poultry. Similarly, large tonnages of manufactured feeds have moved in new directions to accommodate broiler growers. The same sort of changes have occurred in respect to baby chicks, equipment for growing chickens, and services of various kinds. As the broiler business became firmly established, many bankers have come to look upon "chicken paper" as among their best risks.

TABLE 3.—THE 10 HIGH AND 10 LOW STATES IN NUMBER OF HENS AND PULLETS ON FARMS, JANUARY 1, 1950. BASED ON ESTIMATES BY THE U. S. DEPARTMENT OF AGRICULTURE.

The 10 High States			*The 10 Low States*		
Rank	*State*	*Number per farm*	*Rank*	*State*	*Number per farm*
1	New Jersey	482	1	Mississippi	26
2	Massachusetts	243	2	South Carolina	27
3	Rhode Island	232	3	Louisiana	31
4	Connecticut	228	4	Alabama	32
5	New Hampshire	192	5	North Carolina	33
6	Iowa	161	6	Georgia	36
7	Pennsylvania	159	7	Arkansas	37
8	Minnesota	155	8	Florida	43
9	California	155	9	Tennessee	43
10	Utah	135	10	New Mexico	45
		United States	82		

TABLE 4.—THE TEN LEADING STATES IN GROSS POULTRY INCOME FROM CHICKENS, EGGS, AND COMMERCIAL BROILERS, 1950. (*Data from U. S. Department of Agriculture.*)

		Millions of dollars			
Rank	*State*	*Chickens*	*Eggs*	*Broilers*	*Total*
1	Pennsylvania	39.2	124.7	13.3	177.2
2	California	24.6	111.6	24.6	160.8
3	Iowa	36.7	116.4	5.3	158.4
4	New York	26.9	98.6	10.6	136.1
5	Minnesota	23.4	107.2	1.9	132.5
6	Texas	26.8	77.8	25.9	130.5
7	Illinois	28.9	75.7	12.7	117.3
8	Indiana	29.1	60.3	25.4	114.8
9	Missouri	29.3	72.9	11.4	113.6
10	Ohio	26.8	80.2	5.5	112.5
United States		598.9	1,802.1	517.0	2,918.0

This brief review of developments should be sufficient to indicate the many opportunities for employment in the various phases of the poultry industry. A profitable exercise for any group of poultry students is to make a list of the many kinds of jobs which must be done in order to keep the industry operating efficiently.

THE NATURE OF POULTRY AND EGG PRODUCTION

There are many ways of measuring both the size and the significance of the poultry industry. Several different charts and tables are therefore included in this chapter to give the reader some conception of the nature of the poultry business as an important part of American agriculture. No single ranking of the states will tell the whole story of their relative importance. While Pennsylvania leads in total gross poultry income, Delaware leads in number of commercial broilers raised and far outranks all other states in the per cent of total farm income realized from poultry products. Iowa produces more eggs than any other state, but New Jersey has twice as many hens and pullets per farm as her nearest competitor.

Largely because of the many technological problems involved, the industry is fairly well concentrated in certain geographical areas. The ten leading states, as listed in Tables 5, 6, 7, and 8, accounted for 51 per cent of all the chicks hatched, 48 per cent of the farm-raised chickens, 54 per cent of the eggs produced, and 67 per cent of the commercial broilers raised in 1950.

TABLE 5.—THE TEN LEADING STATES IN NUMBERS OF CHICKS HATCHED BY COMMERCIAL HATCHERIES, 1950, WITH COMPARISONS. BASED ON ESTIMATES BY THE U. S. DEPARTMENT OF AGRICULTURE

Rank	State	Chicks hatched (millions) 1950	1945–49 av.	Per cent increase 1950 over 1949
1	Indiana	97.5	97.8	−3
2	Missouri	86.7	96.4	−8
3	Georgia	86.0	48.4	25
4	Illinois	84.3	103.4	−11
5	California	81.9	72.0	0
6	Maryland	81.7	64.0	3
7	Iowa	76.6	87.9	−5
8	Texas	67.3	55.7	10
9	Pennsylvania	65.7	64.0	4
10	Ohio	60.4	62.4	−5
	United States	1,538.2	1,388.6	2

About 13 per cent of all the eggs produced in 1950, and 23 per cent of all the farm-raised chickens were consumed in farm households. By contrast, less than 1 per cent of the commercial broilers raised were consumed in the households of producers. In many of the southern states, where small flocks predominate, from 30 to 40 per cent of the total egg production and as much as 50 to 60 per cent of the farm-raised poultry, is consumed on the farms of producers.

Over one-half of the farms reporting chickens in 1930, and again in 1940, had flocks of fewer than 50 each, and the average for these

TABLE 6.—THE TEN LEADING STATES IN NUMBERS OF CHICKENS RAISED, EXCLUDING COMMERCIAL BROILERS, 1950, WITH COMPARISONS. BASED ON ESTIMATES BY THE U. S. DEPARTMENT OF AGRICULTURE

		Number raised (millions)		
Rank	*State*	*1950*	*1945–49 av.*	*Per cent increase 1950 over 1949*
1	Iowa	43.6	52.2	−9
2	Texas	35.9	41.9	−13
3	Pennsylvania	35.7	38.1	−11
4	Minnesota	33.7	41.2	−12
5	Missouri	32.2	37.4	−13
6	Illinois	30.0	36.0	−9
7	Indiana	30.0	32.1	−7
8	California	28.5	28.0	−5
9	Ohio	27.4	30.4	−9
10	Nebraska	23.4	27.6	−5
United States		670.3	756.2	−10

TABLE 7.—THE TEN LEADING STATES IN NUMBERS OF EGGS PRODUCED, 1950, WITH COMPARISONS. BASED ON ESTIMATES BY THE U. S. DEPARTMENT OF AGRICULTURE

		Number of eggs (millions)		
Rank	*State*	*1950*	*1945–49 av.*	*Per cent increase 1950 over 1949*
1	Iowa	4,788	4,346	9
2	Minnesota	4,261	3,915	10
3	Pennsylvania	3,377	2,958	9
4	California	3,233	2,527	8
5	Missouri	3,004	2,786	6
6	Illinois	2,983	2,728	7
7	Texas	2,877	2,979	2
8	Ohio	2,647	2,571	3
9	Wisconsin	2,518	2,425	2
10	New York	2,514	2,211	8
United States		60,046	55,658	6

TABLE 8.—THE TEN LEADING STATES IN NUMBERS OF COMMERCIAL BROILERS RAISED, 1950, WITH COMPARISONS. BASED ON ESTIMATES BY THE U. S. DEPARTMENT OF AGRICULTURE

		Number raised (millions)		
Rank	*State*	*1950*	*1945–49 av.*	*Per cent increase 1950 over 1949*
1	Delaware	81.2	61.0	13
2	Georgia	62.9	31.9	38
3	Maryland	54.4	37.8	13
4	Arkansas	49.2	22.4	23
5	Virginia	40.0	27.4	5
6	Texas	33.4	15.3	32
7	Indiana	27.9	8.4	38
8	North Carolina	25.0	17.8	14
9	California	23.5	14.5	13
10	Mississippi	17.0	4.2	81
United States		616.2	349.4	23

3,000,000 farms was 23 chickens per flock. But the other half of the flocks are getting larger, and an increasing percentage of total egg production is coming from flocks of 400 and more hens. Such flocks tend to be more profitable for their owners. Because there is more invested in the larger flocks, they usually get better care which, in turn, results in higher egg production. Furthermore, the larger

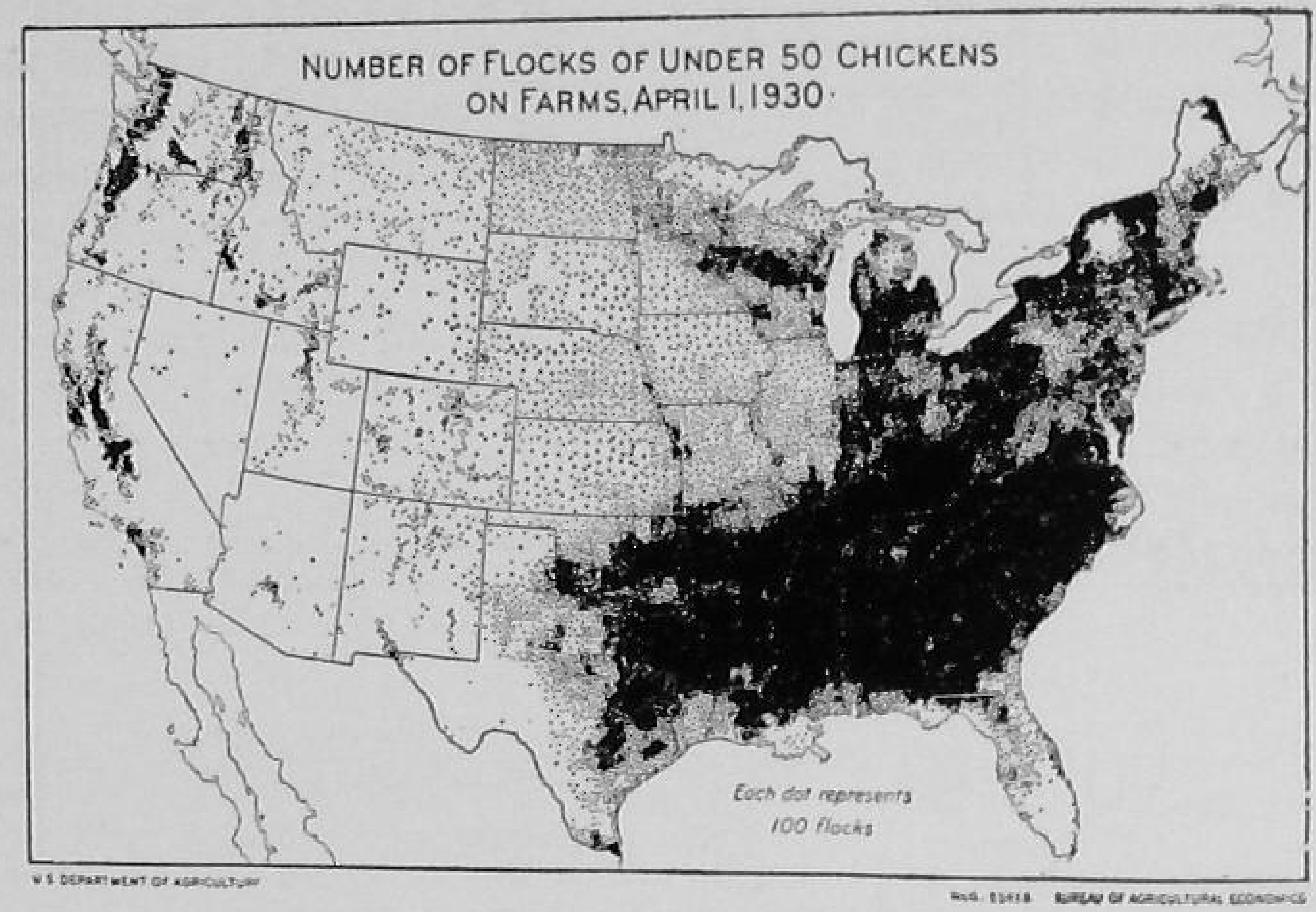


FIG. 5.—The distribution of farm flocks of under 50 chickens, April 1, 1930. Each dot represents 100 flocks, or about 2300 chickens. (*From the U. S. Department of Agriculture.*)

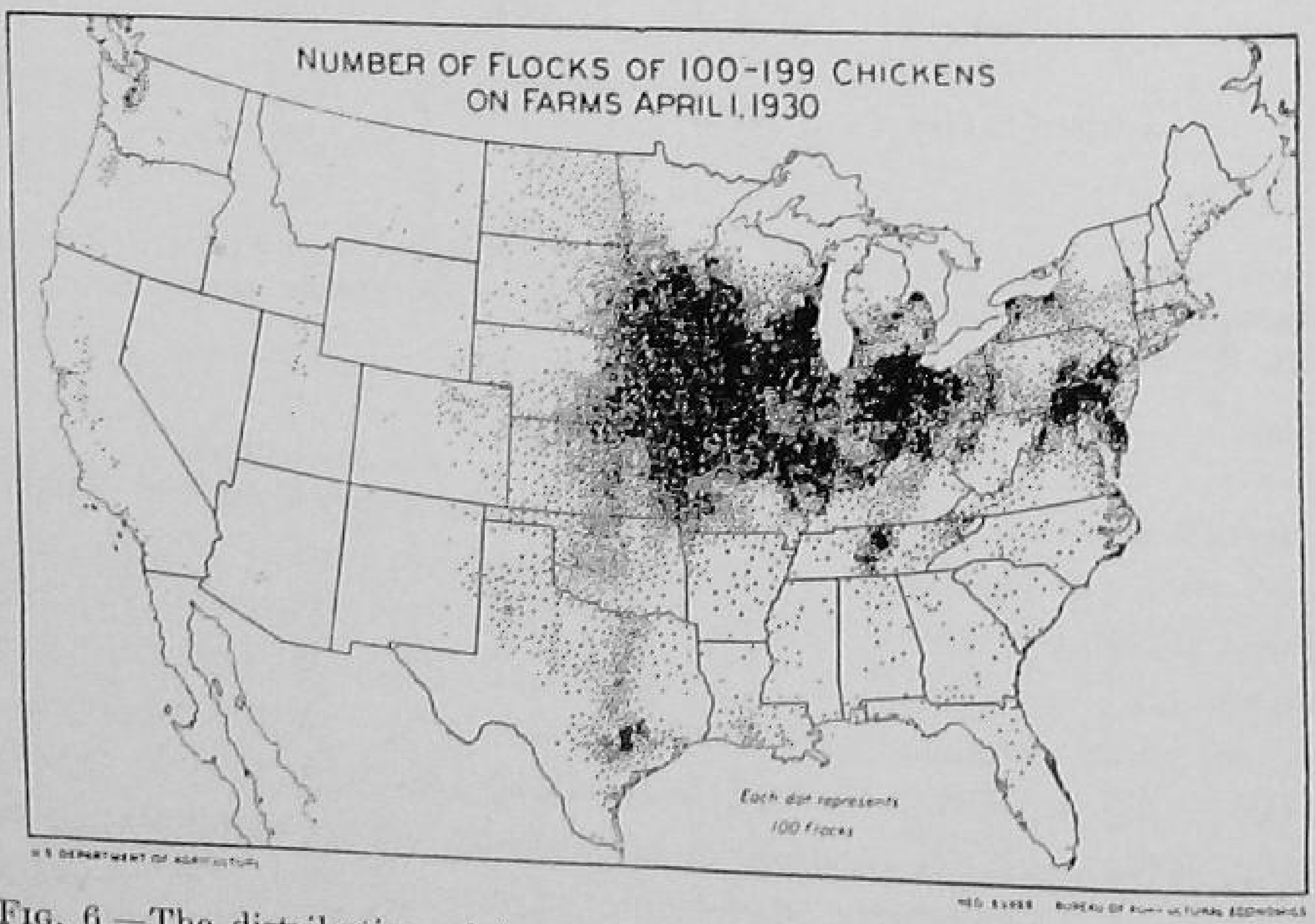


FIG. 6.—The distribution of farm flocks of 100 to 199 chickens. April 1, 1930. Each dot represents 100 flocks, or about 12,700 chickens. (*From the U. S. Department of Agriculture.*)

volume of eggs makes it worth while to follow practices which improve the average quality of eggs marketed, and to search for the best possible outlet, thus insuring a better product for the consumer and a higher average price for the producer.

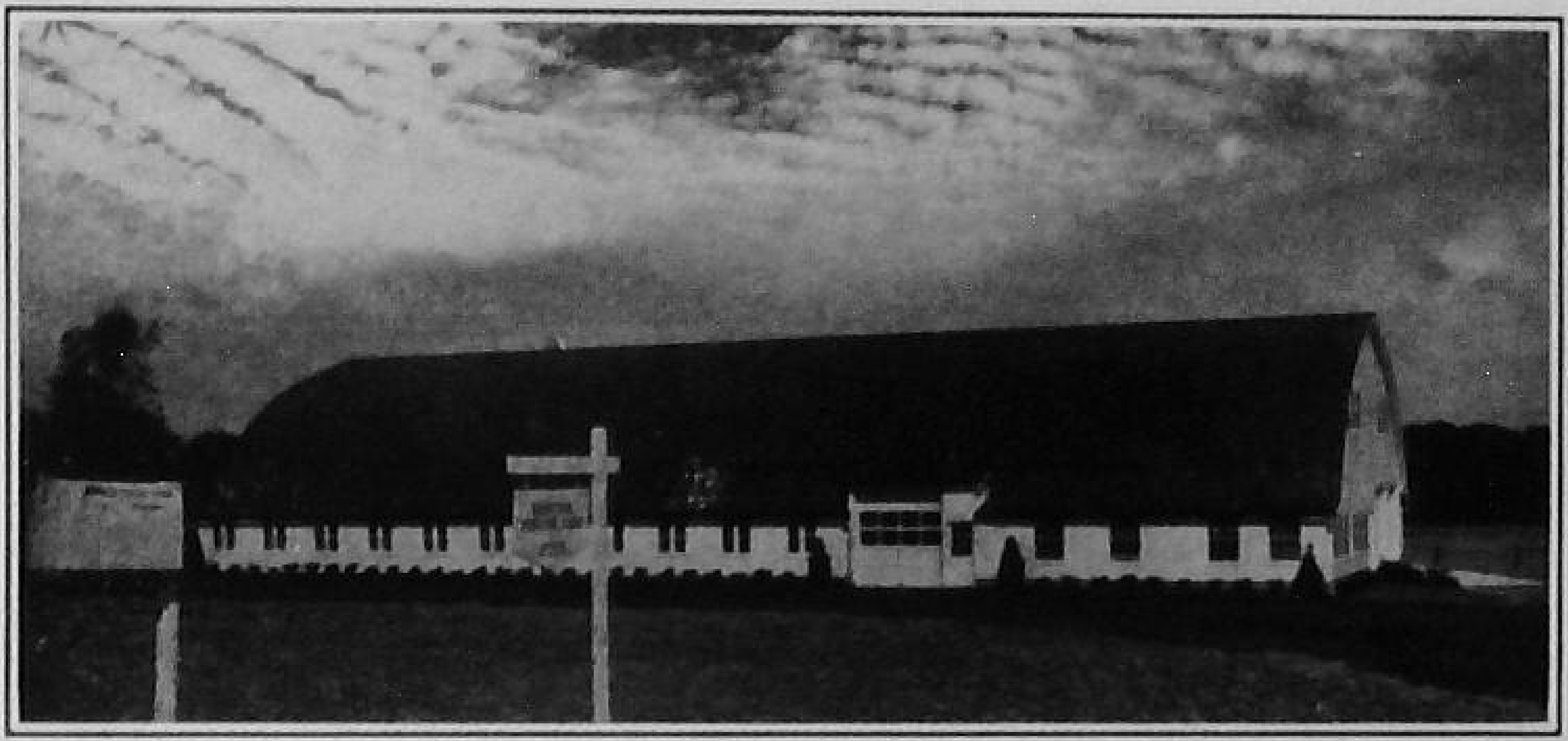


FIG. 7.—New hatchery building on the Babcock Poultry Farm, Ithaca, N. Y. Such breeder-hatcheries often put out upwards of two million chicks a year. (*Courtesy of Poultry Tribune.*)

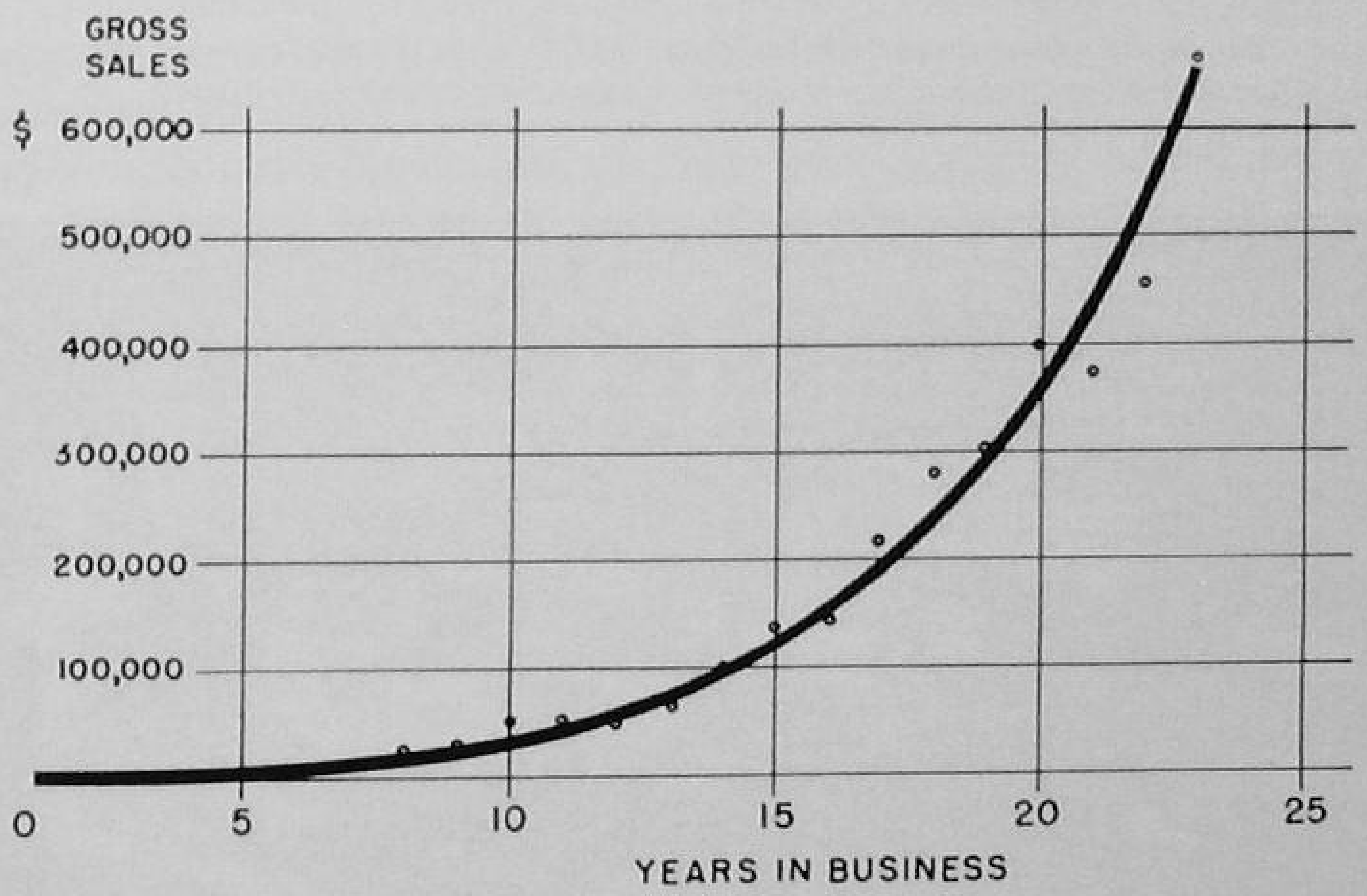


FIG. 8.—Developing a successful business takes years of hard work, but after 23 years this breeder-hatchery was doing better than a half-million-dollar business annually.

Large production units are becoming the rule rather than the exception in many areas. Brief reference to the hatchery business will illustrate the point. A hatcheryman who today needs 40,000 breeding females in his supply flocks has probably been encouraging his flock owners to expand their operations, and may have under

contract no more than 40 flocks averaging 1000 hens each. Ten years ago he probably would have had to deal with 200 flock owners having flocks of 200 hens each, in order to operate the same total capacity. Of course part of this change has come about because progressive hatcherymen realize that their flock owners are, in a very

FIG. 9.—Modern attractive buildings like this reflect the growth and stability of the poultry business. (*Courtesy of Poultry Tribune.*)

FIG. 10.—The poultry industry holds several important trade conventions and conferences each year. This is a view of the exhibit hall at the Fact Finding Conference in Kansas City. (*Courtesy of U. S. Egg and Poultry Magazine.*)

real sense, a most important part of their business, and compensate them accordingly.

Large commercial egg farms are becoming common in many parts of the country. There are farms in the Middle West, as well as along the east and west coasts, on which 50,000 to 60,000 layers are housed annually. Many commercial broiler growers market upwards of 60,000 broilers a year. There are about 100 large hatcheries in the country, each with sufficient incubator capacity to set 500,000 or more eggs at one time, and perhaps 10,000 smaller operators. And there are breeding farms, perhaps more accurately described as breeder-hatcheries, on which the gross annual income is in excess of $500,000. Poultry and egg production is truly big business.

OTHER PHASES OF THE POULTRY INDUSTRY

This book is concerned primarily with those things that have to do directly with production, and other phases of the industry can be given but brief mention. It is important to remember, however, that the poultry industry as it exists today involves a great deal more than the farm production of poultry and eggs for food or other purposes.

The business of producing chicks for sale has enjoyed a remarkable growth since March 15, 1918, when shipments of day-old chicks were first admitted to the mails. The appearance, in 1922, of room-type mammoth incubators of large capacity gave added impetus to the business and made rapid expansion an easy matter. The number of commercial hatcheries in the United States increased from an estimated 250 in 1918 to more than 10,000 in 1927. Considerable further expansion took place after that date, but much of it consisted in enlarging the capacity of hatcheries already established. The incubating of eggs and the hatching of chicks has literally been taken off the farm, and this change has had marked effects on many other practices in the industry.

More than 30 million breeding hens are tested annually for pullorum disease, and comparable numbers of chickens must be vaccinated for the prevention of such diseases as fowl pox, laryngotracheitis and Newcastle disease.

A necessary accompaniment of commercial hatching is artificial brooding. Without modern brooding equipment it would have been impossible for the industry to reach anything like its present size.

Under the impetus of a demand growing out of war conditions, the business of drying eggs mushroomed from almost nothing to plants with an annual capacity of around 400 million pounds. This is sufficient to take the total egg production of about 125 million hens.

Adequate rations are essential to such expansion, and in this direction the industry has made such strides that more is known

about the nutritional requirements of the chicken than about those of any other farm animal. This, and the fact that several different nutrients can now be produced synthetically at low cost, makes it possible to produce a tremendous tonnage of feed which is vastly superior to the most carefully prepared mixtures of a few years ago. Of the more than 30 million tons of manufactured feeds, about two-thirds, or 20 million tons, are poultry feeds.

Both changing poultry practices and increased production call for new equipment beyond the ordinary replacement needs of the industry. Incubators, brooders, feeding equipment, egg cases, chick boxes and many other articles must be made in increasing

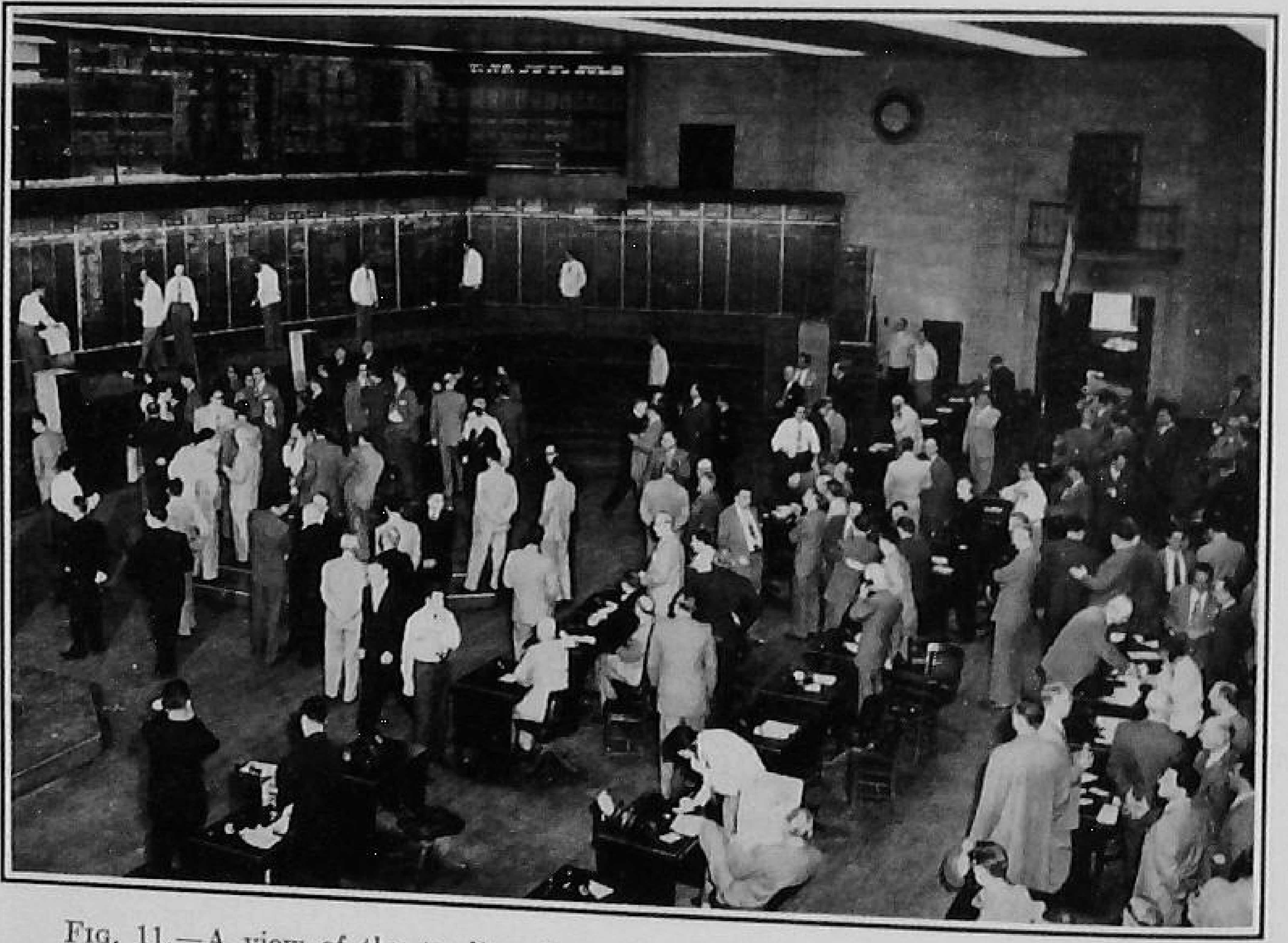


FIG. 11.—A view of the trading floor on the Chicago Mercantile Exchange.

numbers as the industry grows. Leg bands, time clocks, battery brooders, laying batteries, egg cartons, glass substitutes, hardware cloth, insulating boards and automatic feeders have been needed to meet changing practices. Many new kinds of labor saving equipment have been introduced into poultry and egg processing plants. Refrigerator units are needed by thousands of retail stores offering pan-ready poultry for sale. New demands take the place of old needs as new ideas develop and older practices are discarded.

Allied Interests.—It is easy to see that feed, equipment and supplies must be manufactured to meet production needs. Just as important, though perhaps not so readily apparent, are the needs for processing equipment, cold storage warehouse facilities, trucks for

the bulk handling of feed and for the transportation of live and dressed poultry and eggs, laboratories for the production of embryo-propagated vaccines, and facilities for getting information about poultry and eggs to the consuming public by way of the press, radio and television.

TABLE 9.—THE TEN LEADING STATES IN POULTRY AND EGG PRODUCTION PER PERSON, 1950. BASED ON ESTIMATES BY THE U. S. DEPARTMENT OF AGRICULTURE AND THE 1950 POPULATION CENSUS.

	Eggs		*Farm-raised chickens*		*Broilers*	
Rank	*State*	*Number*	*State*	*Number*	*State*	*Number*
1	Iowa	1825	South Dakota	20	Delaware	255
2	South Dakota	1730	Nebraska	18	Arkansas	26
3	Minnesota	1429	Iowa	17	Maryland	23
4	Nebraska	1384	Kansas	12	Maine	19
5	Kansas	1083	Minnesota	11	Georgia	18
6	North Dakota	857	North Dakota	10	Virginia	12
7	New Hampshire	777	New Hampshire	9	New Hampshire	9
8	Missouri	760	Missouri	8	Mississippi	8
9	Wisconsin	733	Indiana	8	West Virginia	8
10	Utah	717	Oklahoma	8	Connecticut	7
United States		398		4.4		4.1

TABLE 10.—THE TEN LEADING STATES IN POULTRY AND EGG PRODUCTION PER SQUARE MILE OF LAND AREA, 1950. BASED ON ESTIMATES BY THE U. S. DEPARTMENT OF AGRICULTURE.

	Eggs		*Farm-raised chickens*		*Broilers*	
Rank	*State*	*Number**	*State*	*Number*	*State*	*Number*
1	New Jersey	285	New Jersey	1978	Delaware	41,065
2	Massachusetts	119	Connecticut	1190	Maryland	5,445
3	Connecticut	118	Massachusetts	1073	Connecticut	2,930
4	Rhode Island	96	Delaware	1007	Massachusetts	1,180
5	Iowa	86	Rhode Island	989	Georgia	1,075
6	Pennsylvania	75	Indiana	828	Virginia	1,003
7	Delaware	72	Iowa	779	Arkansas	933
8	Ohio	64	Pennsylvania	714	New Jersey	820
9	Indiana	62	Ohio	666	Rhode Island	783
10	Maryland	54	Maryland	641	Indiana	772
United States		20		225		207

* Thousands

The Chicago Mercantile Exchange, at 110 North Franklin Street, provides a trading floor where buyers and sellers can meet each business day to trade in eggs, tom and hen turkeys, butter and other commodities. Contracts traded in 1950 included 110,114 cars of eggs. This provides a futures market which is necessary for hedging operations, and which automatically indicates from day to day the combined judgment of a large group of buyers and sellers as to the value of the various commodities traded. Because of the limitations surrounding trading in futures, the overall effect is a highly desirable

stabilizing of the market. The maximum daily price range for eggs, for example, is 2 cents a dozen above or below the previous day's settling price. The New York Mercantile Exchange provides similar trading facilities in that city.

The nation's cold storage warehouses provided holding space in 1950 for more than 7 million cases of shell eggs, 250 million pounds of frozen eggs, 100 million pounds of dried eggs, and nearly 300 million

TABLE 11.—THE MORE IMPORTANT CHARACTERISTICS OF SOME REPRESENTATIVE BREEDS OF CHICKENS

Breed	Standard weight, pounds		Type of comb	Color of earlobe	Color of skin	Color of shank	Shanks feathered?	Color of egg
	Cock	Hen						
American Breeds:								
Plymouth Rock	9½	7½	Single	Red	Yellow	Yellow	No	Brown
Wyandotte	8½	6½	Rose	Red	Yellow	Yellow	No	Brown
Rhode Island Red	8½	6½	Single and rose	Red	Yellow	Yellow	No	Brown
Jersey Black Giant	13	10	Single	Red	Yellow	Black	No	Brown
New Hampshire	8½	6½	Single	Red	Yellow	Yellow	No	Brown
Asiatic Breeds:								
Brahma (Light)	12	9½	Pea	Red	Yellow	Yellow	Yes	Brown
Cochin	11	8½	Single	Red	Yellow	Yellow	Yes	Brown
Langshan (Black)	9½	7½	Single	Red	White	Bluish-black	Yes	Brown
English Breeds:								
Australorp	8½	6½	Single	Red	White	Dark slate	No	Brown
Cornish (Dark)	10	7½	Pea	Red	Yellow	Yellow	No	Brown
Dorking (Silver-gray)	9	7	Single	Red	White	White	No	White
Orpington (Buff and White)	10	8	Single	Red	White	White	No	Brown
Sussex	9	7	Single	Red	White	White	No	Brown
Mediterranean Breeds:								
Leghorn	6	4½	Single and rose	White	Yellow	Yellow	No	White
Minorca (S. C. Black)	9	7½	Single	White	White	Dark slate	No	White
Ancona	6	4½	Single and rose	White	Yellow	Yellow	No	White
Andalusian (Blue)	7	5½	Single	White	White	Slaty blue	No	White

pounds of chicken and turkey meat. All of these products had to first be moved through processing plants, and they had to be packaged, financed, transported and sold. Some of the specialized equipment used in poultry and egg processing plants is illustrated and described in Chapter 13.

THE BREEDS OF CHICKENS

Of the nearly 200 varieties of chickens listed in the American Standard of Perfection, not more than five are of commercial importance today. They are the White Leghorn, the New Hampshire, the White Plymouth Rock, the Barred Plymouth Rock and the Rhode Island Red. Together they accounted for 75 per cent of all chickens raised in 1943. No other breed accounted for as much as 2 per cent, but crosses and mixed breeds together made up about 20 per cent of the total.

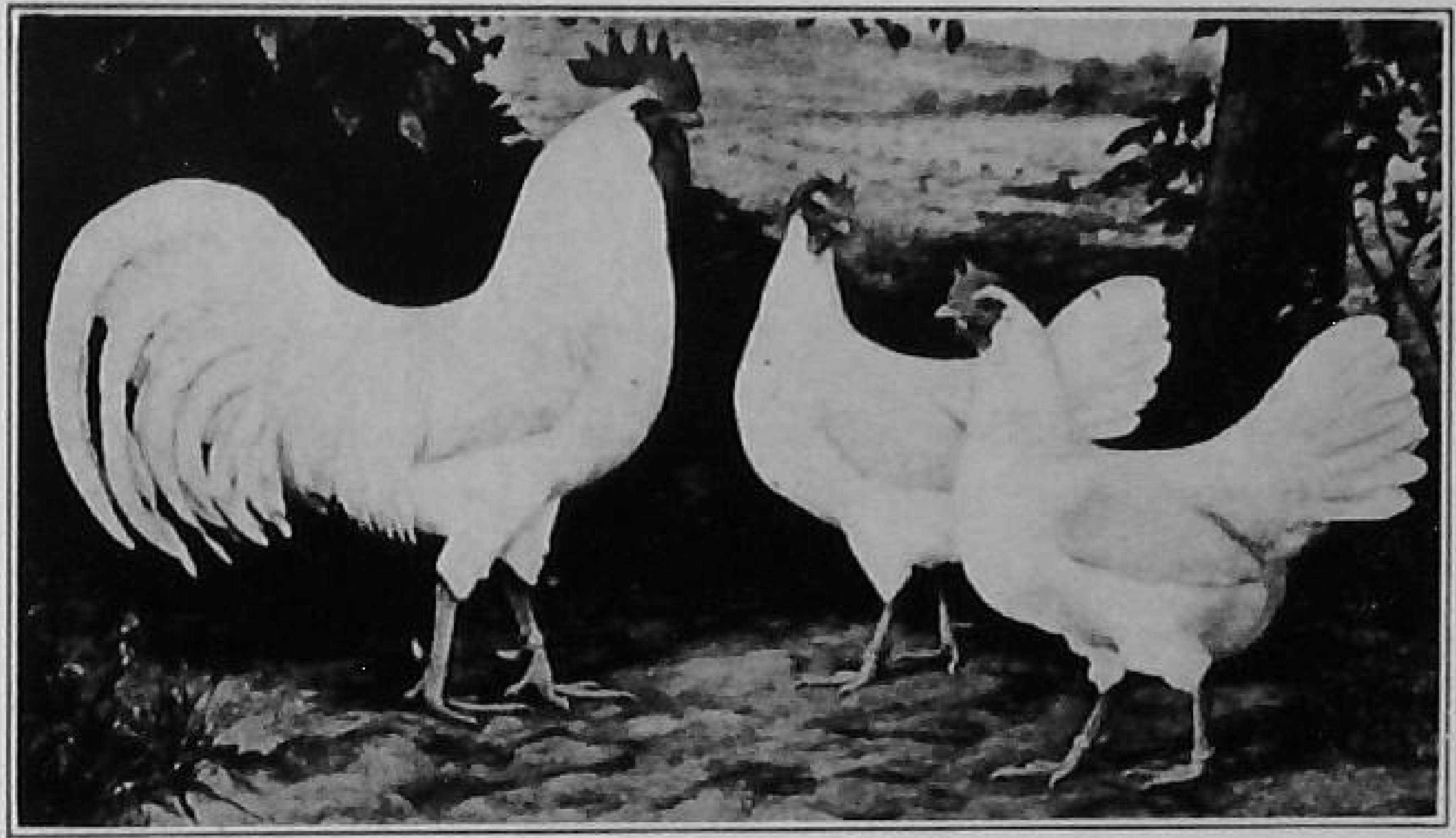


Fig. 12.—Single Comb White Leghorns (Mediterranean). *(Courtesy of Poultry Tribune.)*

Leghorns made up 40 per cent or more of all chickens raised in 1943 in New Jersey, Pennsylvania, Wisconsin, Minnesota, Oklahoma, Texas, Utah, Nevada, Washington, Oregon, and California. For the entire country they accounted for 34 per cent of the total.

Plymouth Rocks made up 40 per cent or more of the total in Michigan, Illinois, Indiana and Kentucky. They accounted for 26 per cent of all the chickens raised in 1943, and of this number 10 per cent were of the Barred and 15 per cent of the White variety.

New Hampshires made up 10 per cent of the total. In their home state they accounted for 50 per cent of all chickens raised in 1943, and in Florida 71 per cent. In Virginia, North Carolina, Idaho, Washington and Oregon, they made up between 30 and 40 per cent of all chickens raised in that year.

Fig. 13.—Barred Plymouth Rocks (American). *(Courtesy of Poultry Tribune.)*

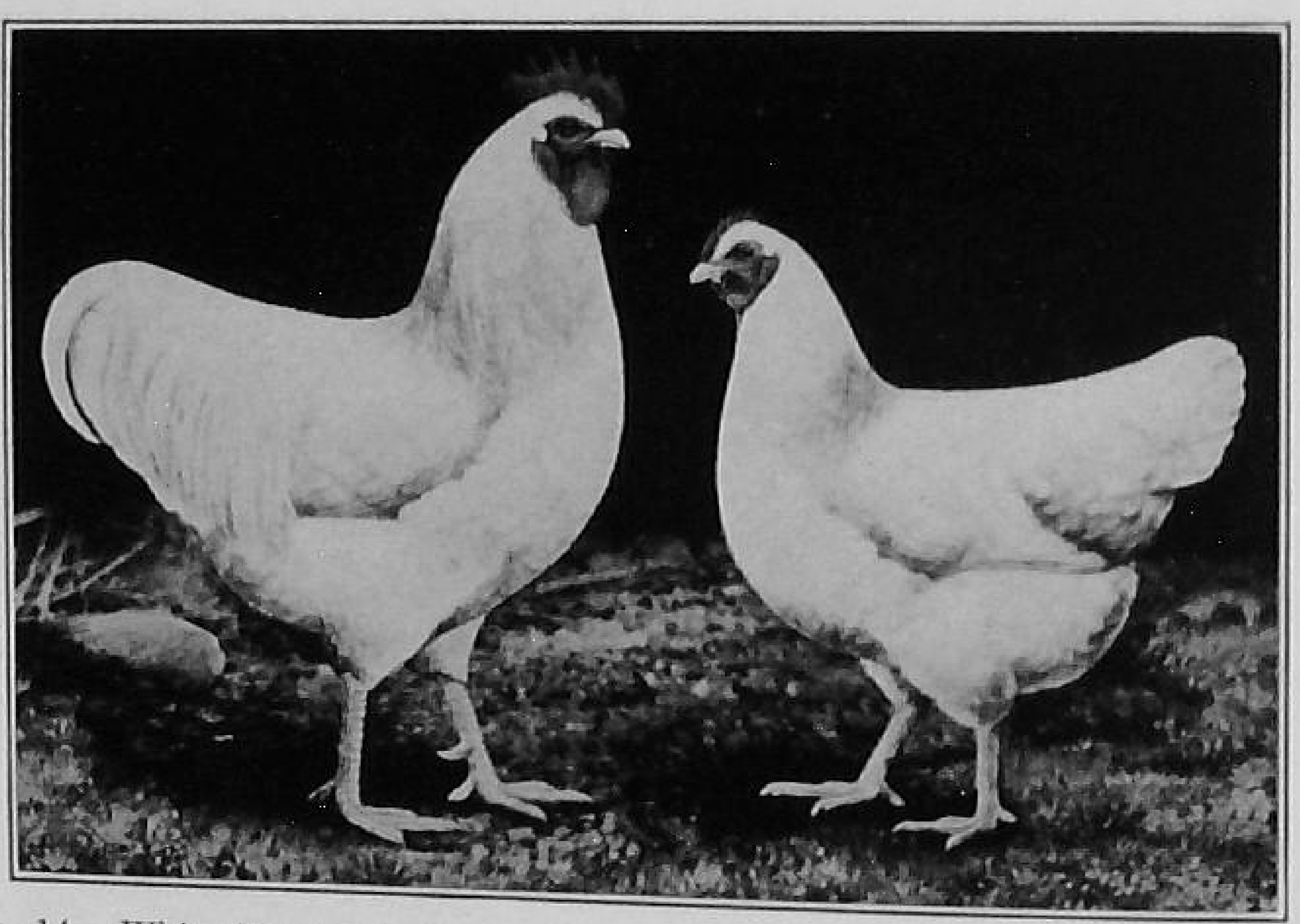


Fig. 14.—White Plymouth Rocks (American). *(Courtesy of Poultry Tribune.)*

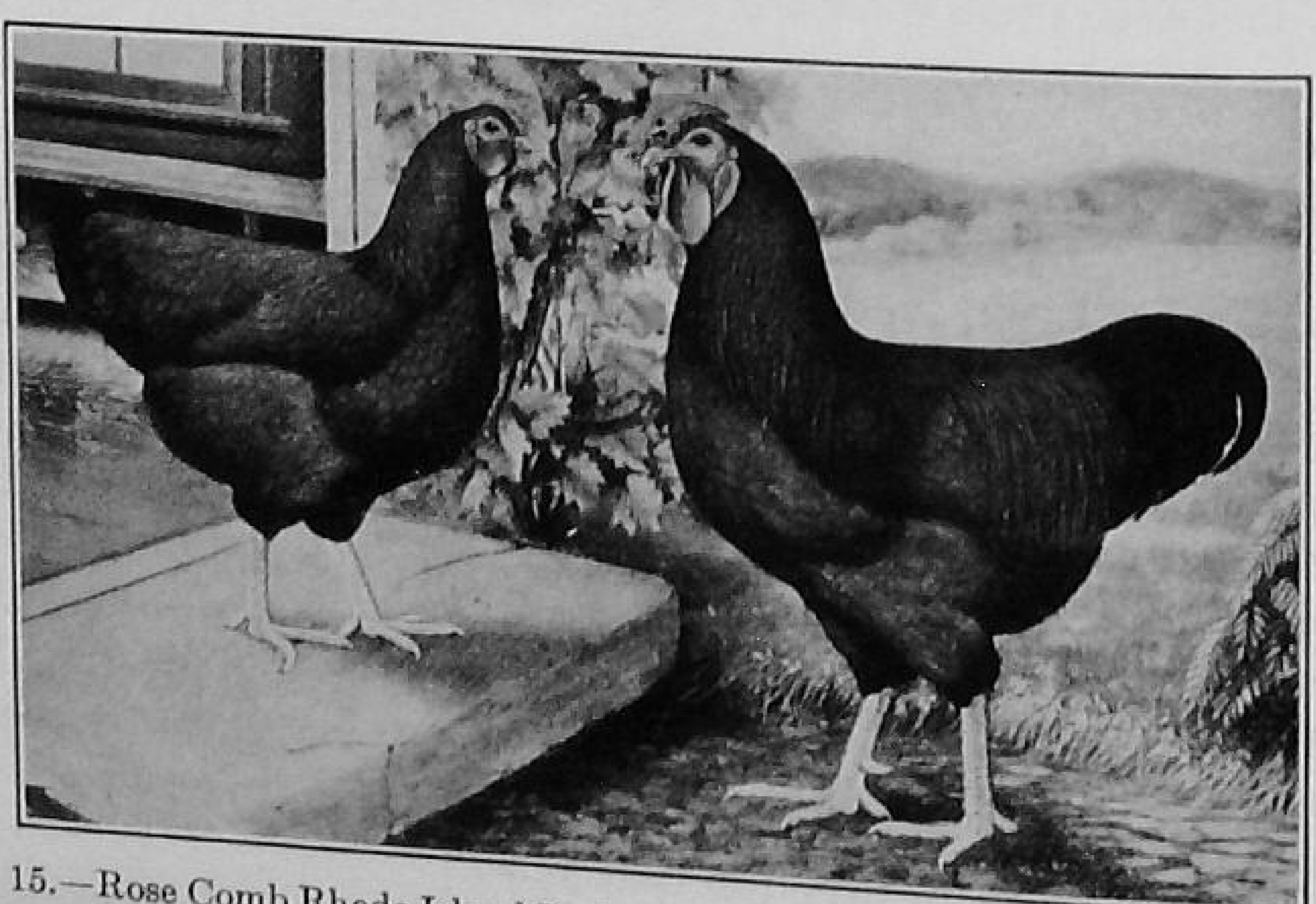


Fig. 15.—Rose Comb Rhode Island Reds (American). *(Courtesy of Poultry Tribune.)*

Rhode Island Reds accounted for 49 per cent of the chickens raised in Massachusetts, 36 per cent in Rhode Island, and 32 per cent in Maine. In no other state outside of New England did they make up as much as 20 per cent. They accounted for $5\frac{1}{2}$ per cent of the chickens raised in the entire country.

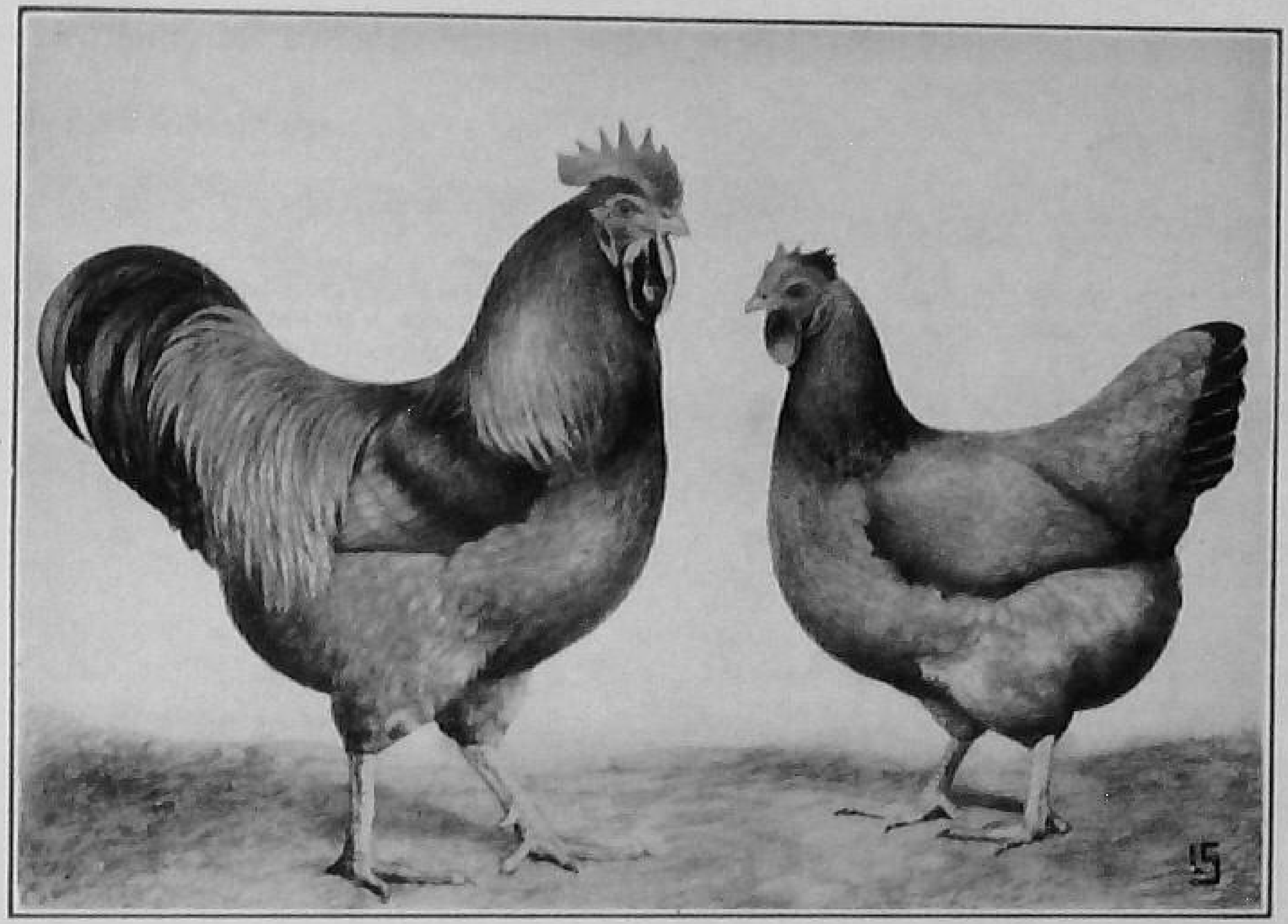


FIG. 16.—New Hampshires (American). *(Courtesy of Poultry Tribune.)*

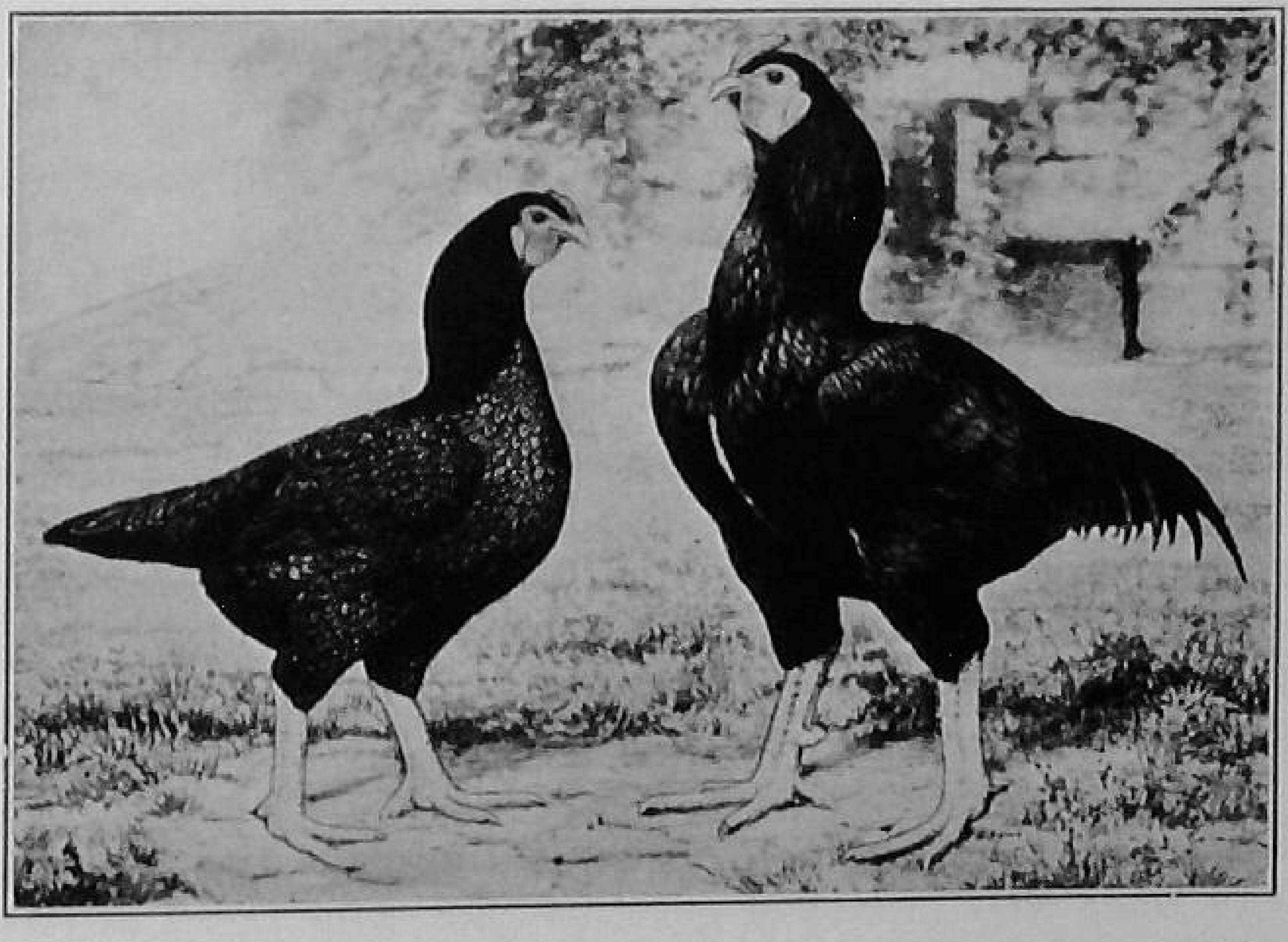


FIG. 17.—Dark Cornish (English). The Cornish is often crossed with other breeds to produce a desirable meat type chicken. *(Courtesy of Poultry Tribune.)*

Nearly one-half of the chickens raised in Connecticut and Delaware, and about one-third of those raised in Maine, Vermont, Rhode Island, and Kansas were crossbreds. For the entire country, 9 per cent were crosses.

The relative importance of breeds and varieties can also be measured by their distribution among hatchery supply flocks. Such data for the more than 36 million chickens in flocks under the supervision in the National Poultry Improvement Plan in 1949–50 are shown in Table 12.

TABLE 12.—CHICKENS IN NPIP HATCHERY SUPPLY FLOCKS AND THEIR DISTRIBUTION BY VARIETIES, 1949–50

Region	Total, millions	New Hampshire per cent	White Leghorn per cent	White Plymouth Rock per cent	Barred Plymouth Rock per cent	Rhode Island Red per cent	Cross Mated per cent	Other per cent
North Atlantic . .	7.6	49	15	3	15	10	7	1
East North Central	8.6	26	24	23	8	2	12	5
West North Central	9.0	21	32	13	2	2	25	5
South Atlantic . .	5.8	68	6	1	2	2	18	3
South Central . .	2.6	44	15	11	7	3	15	5
Western	2.6	39	42	2	1	5	9	2
Total, 47 states (Nevada not included)	36.2	39	22	10	6	4	15	4
			Total for 39 States Reporting in Both 1944–45 and 1949–50					
1944–45	17.6	21	26	17	12	8	10	6
1949–50	31.1	39	21	11	6	4	15	4

Popularity of the several varieties is far from uniform throughout the country. White Leghorns made up more than half the breeding stock in New Jersey, Wisconsin, Minnesota, New Mexico, Utah and California, but less than 1 per cent in New Hampshire, Vermont, Rhode Island and Georgia. New Hampshires, which have been gaining in popularity in recent years, accounted for more than 75 per cent of the breeding stock in New Hampshire, Virginia, North Carolina, South Carolina, Georgia, Florida and Alabama, and between 50 and 75 per cent in seven other states. On the other hand, they represented less than 10 per cent of the breeding stock in Wisconsin and Minnesota.

Barred Plymouth Rocks exceeded 25 per cent in only three states, Vermont, Rhode Island and Connecticut, and fell below 1 per cent in sixteen states. White Plymouth Rocks, which have been losing ground, exceeded 25 per cent in Illinois, North Dakota and Wyoming, and fell below 1 per cent in 11 states. Rhode Island Reds exceeded 30 per cent in Massachusetts and Rhode Island, but in only six others did they account for as much as 10 per cent, and in eleven states they were down to 1 per cent or below.

Further changes may be expected, because poultrymen can shift quickly when they find clear evidence that some breed or strain is superior to what they have been using. A preference for white broilers, for example, could quickly reverse the trend in popularity of White Plymouth Rocks.

With increased emphasis being placed on performance—whether it be growth or egg production—poultrymen have become less and less concerned about the supposed "purity" of the breeds with which they work. If dominant white plumage and early feathering are needed in White Plymouth Rocks, they do not object too much to introducing these characters by the use of White Leghorns if necessary, in spite of the rigorous selection which must follow the original introduction. They are not disturbed by a few black feathers in a white fowl, by an extra point on a single comb, or by a little down between the toes, *provided* growth and egg production are satisfactory. This change in attitude, like the growing interest in cross breeding and in the production of hybrid chickens, has developed as a part of present-day commercial poultry and egg production.

A SELECTED LIST OF TWENTY-FIVE TITLES FROM WHICH TO BUILD A WORKING POULTRY LIBRARY

(The shorter list of ten, indicated by asterisks, will be adequate for many purposes.)

1. *AMERICAN POULTRY ASSOCIATION, INC., 1945: "American Standard of Perfection." 492 pp., Station A, Box 104, Atlanta, Ga.
2. *BARGER, E. H., AND CARD, L. E., 1949: "Diseases and Parasites of Poultry." 4th ed., 400 pp., Lea & Febiger, Philadelphia.
3. *BENJAMIN, E. W., PIERCE, H. C., AND TERMOHLEN, W. D., 1949: "Marketing Poultry Products." 4th ed., 389 pp., John Wiley & Sons, Inc., New York.
4. BIESTER, E. H., AND SCHWARTE, L. H., 1948: "Diseases of Poultry." 2nd ed., 1154 pp., The Iowa State College Press, Ames, Iowa.
5. BRADLEY, O. C., AND GRAHAME, TOM, 1950: "The Structure of the Fowl." 3rd ed., 128 pp., J. B. Lippincott Company, Philadelphia.
6. EWING, W. R., 1947: "Handbook of Poultry Nutrition." 3rd ed., 1402 pp., W. R. Ewing, South Pasadena, Calif.
7. HARTMAN, R. C., 1951: "Keeping Chickens in Cages." 236 pp., Roland C. Hartman, Redlands, Calif.
8. HARTMAN, R. C., AND VICKERS, G. S., 1946: "Hatchery Management." Revised edition, 404 pp., Orange Judd Publishing Co., Inc., New York.
9. *HOFFMANN, E., AND GWIN, J. M., 1951: "Successful Broiler Growing." 2nd ed., 256 pp., Watt Publishing Company, Mount Morris, Ill.
10. *HUTT, F. B., 1949: "Genetics of the Fowl." 590 pp., McGraw-Hill Book Company, Inc., New York.
11. JULL, M. A., 1952: "Poultry Breeding." 3rd ed., 398 pp., John Wiley & Sons, Inc., New York.
12. JULL, M. A., 1951: "Poultry Husbandry." 3rd ed., 526 pp., McGraw-Hill Book Company, Inc., New York.
13. JULL, M. A., 1947: "Raising Turkeys, Ducks, Geese, Game Birds." 467 pp., McGraw-Hill Book Company, Inc., New York.
14. *LERNER, I. M., 1950: "Population Genetics and Animal Improvement." (As illustrated by the inheritance of egg production.) 342 pp., Cambridge University Press, Cambridge, England.
15. *MARSDEN, H. W., AND MARTIN, J. H., 1949: "Turkey Management." 5th ed., 774 pp., The Interstate, Danville, Ill.
16. MORRISON, F. B., 1948: "Feeds and Feeding." 21st ed., 1207 pp., The Morrison Publishing Co., Ithaca, New York.
17. NEEDHAM, J., 1931: "Chemical Embryology." 3 vols., 2021 pp., The Macmillan Company, New York.
18. PATTEN, B. M., 1951: "Early Embryology of the Chick." 4th ed., 244 pp., The Blakiston Company, Philadelphia.
19. *PAYNE, L. F., AND AVERY, T. B., 1950: "International Poultry Guide for Flock Selection." 2nd ed., 252 pp., International Baby Chick Association (now American Poultry and Hatchery Federation), Kansas City, Mo.

20. RICE, J. E., HALL, G. O., AND MARBLE, D. R., 1930: "Judging Poultry for Production." 425 pp., John Wiley & Sons, Inc., New York.
21. ROMANOFF, A. L., AND ROMANOFF, ANASTASIA J., 1949: "The Avian Egg." 908 pp., John Wiley & Sons, Inc., New York.
22. *TAYLOR, L. W., Editor, 1949: "Fertility and Hatchability of Chicken and Turkey Eggs." 423 pp., John Wiley & Sons, Inc., New York.
23. *TITUS, H. W., 1949: "The Scientific Feeding of Chickens." 2nd ed., 253 pp., The Interstate, Danville, Ill.
24. WINTER, A. R., AND FUNK, E. M., 1951: "Poultry Science and Practice." 3rd ed., 662 pp., J. B. Lippincott Company, Philadelphia.
25. World's Poultry Congress Proceedings:
    1st, Holland, 1921: 2 vols., 611 pp.
    2nd, Spain, 1924: 2 vols., 905 pp.
    3rd, Canada, 1927: 538 pp.
    4th, England, 1930: 1023 pp.
    5th, Italy, 1933: 4 vols., 1487 pp.
    6th, Germany, 1936: 3 vols., 1173 pp.
    7th, United States, 1939: 551 pp.
    8th, Denmark, 1948: 752 pp.
    9th, France, 1951: 643 pp.

A LIST OF 40 PERIODICALS WHICH REGULARLY OR OCCASIONALLY CONTAIN ARTICLES RELATING TO RESEARCH WITH POULTRY AND EGGS

1. Agricultural Engineering
2. American Egg and Poultry Review
3. American Journal of Anatomy
4. American Journal of Hygiene
5. American Journal of Veterinary Research
6. Anatomical Record
7. Archives of Biochemistry and Biophysics
8. Biological Abstracts
9. British Journal of Nutrition
10. Canadian Journal of Research
11. Chemical Abstracts
12. Cornell Veterinarian
13. Endocrinology
14. Federation Proceedings
15. Food Research
16. Food Technology
17. Genetics
18. Growth
19. Heredity
20. Journal of Agricultural Science
21. Journal of Biological Chemistry
22. Journal of Economic Entomology
23. Journal of Endocrinology
24. Journal of Experimental Biology
25. Journal of Experimental Zoology
26. Journal of Genetics
27. Journal of Heredity
28. Journal of Home Economics
29. Journal of Morphology
30. Journal of Nutrition
31. Journal of Parasitology
32. Nutrition Abstracts and Reviews
33. Parasitology
34. Physiological Reviews
35. Physiological Zoology
36. Poultry Science
37. Proceedings of the Society for Experimental Biology and Medicine
38. Science
39. Scientific Agriculture
40. U. S. Egg and Poultry Magazine.

CHAPTER 2

THE STRUCTURE OF THE CHICKEN AND THE FORMATION OF THE EGG

THE FOWL AS A LIVING ORGANISM

In comparison with most other animals, birds are often spoken of as fast-living creatures. Structurally, too, they are among the most highly specialized of vertebrates, many of their modifications being in the nature of adaptations for flight. Their coating of feathers is sufficient to set them apart from all other forms, but they are also characterized by being warm-blooded, by having a high metabolic rate, and by the fact that development of the young takes place, for the most part, outside the body of the mother.

The body temperature of the fowl is higher than that of other domestic animals, and because of a more or less regular diurnal variation the recorded temperatures show a greater range than is found in other farm animals. The reported temperatures range from a minimum of 105° to a maximum of 109.4° F., depending upon the time of day the observations were made. The average noon figure is about 107° F. The minimum temperature during each twenty-four hour period occurs between 10 P.M. and midnight, whereas the maximum occurs some time during the afternoon.

The fowl is a rapid breather and its pulse-rate is high. Records taken of the heart-beat of the chick embryo indicate that the pulse-rate rises rapidly from about 130 to about 230 beats per minute, during the first nine days of incubation. It then rises but little during the next two or three days, and remains remarkably uniform during the remainder of the incubation period.

The heart-rate again rises sharply during and immediately after hatching, and by the end of twelve hours it is about 300 beats per minute, where it remains reasonably constant. This rate is also characteristic of the adult fowl.

There is a definite relationship between body weight and heart rate. Small fowls such as Leghorn females have a resting heart rate of about 330 beats per minute, while large fowls such as Rhode Island Red males average below 250. There is also a regular diurnal variation in the normal heart rate, associated with the normal diurnal variation in temperature. Any excitement will cause an immediate and pronounced acceleration in heart rate. Dropping

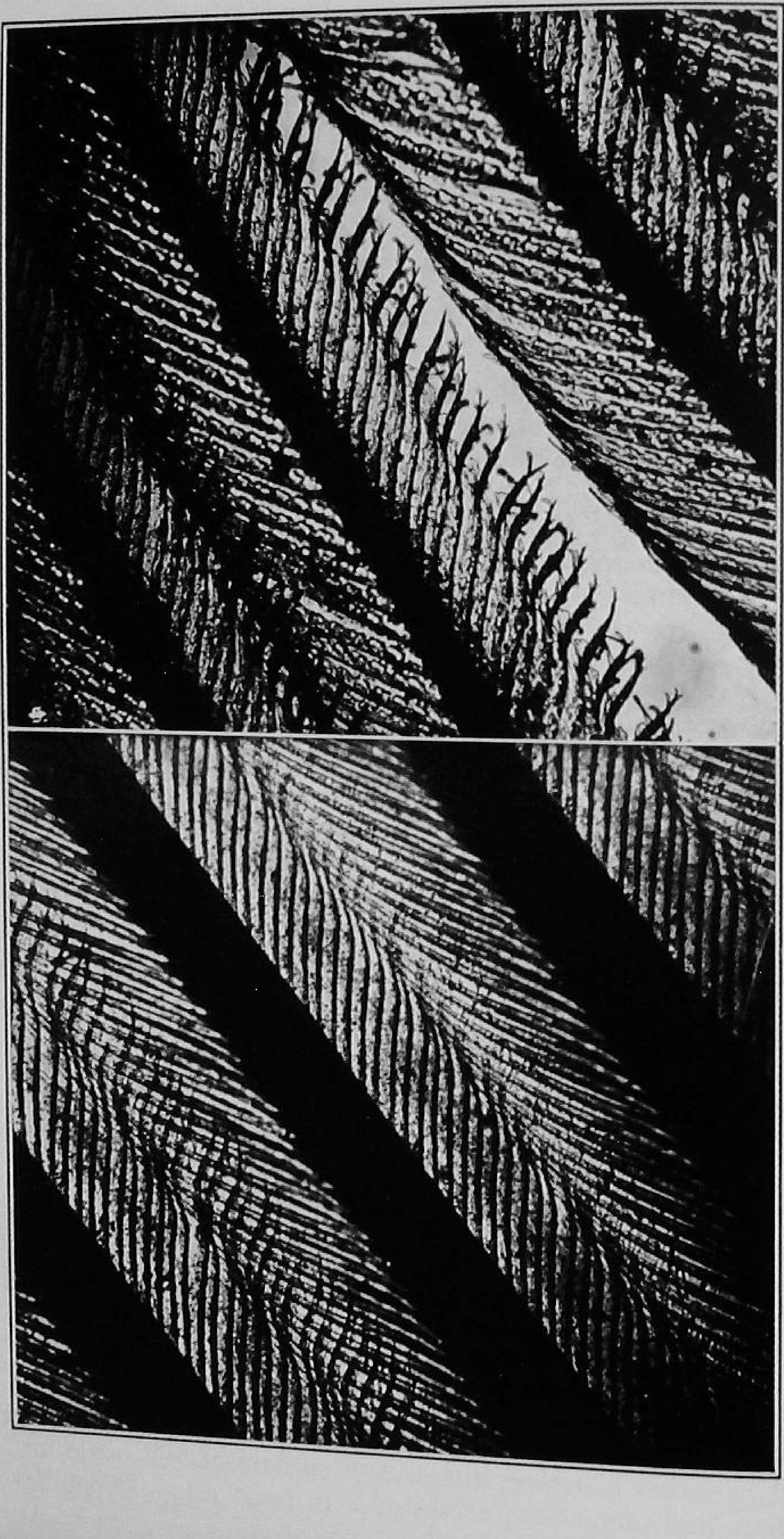


Fig. 18.—Feather structure is very intricate. *Left*, a small section from a wing feather magnified 100 times. The heavy diagonal lines are barbs, the fine interlocked ones are barbules. The shaft, at the left, is not shown. *Right*, a similar section in which two barbs have been pulled apart to show the hooklets on the distal barbules.

a day-old chick has been shown to cause the heart rate to increase from 300 to 560 beats per minute.

Feathers.—Feathers help to protect the bird from physical injury, and are also of a great deal of aid in keeping the body warm. The wing feathers are, of course, essential to flight. The annual renewal of the feather coat constitutes a considerable physiological expense to the fowl, since the feathers make up from 4 to 9 per cent of the empty live weight, depending on the age and sex of the individual.

Though the body surface of most birds is almost entirely covered by feathers, there are only a very few species in which the feathers

A

B

C

D

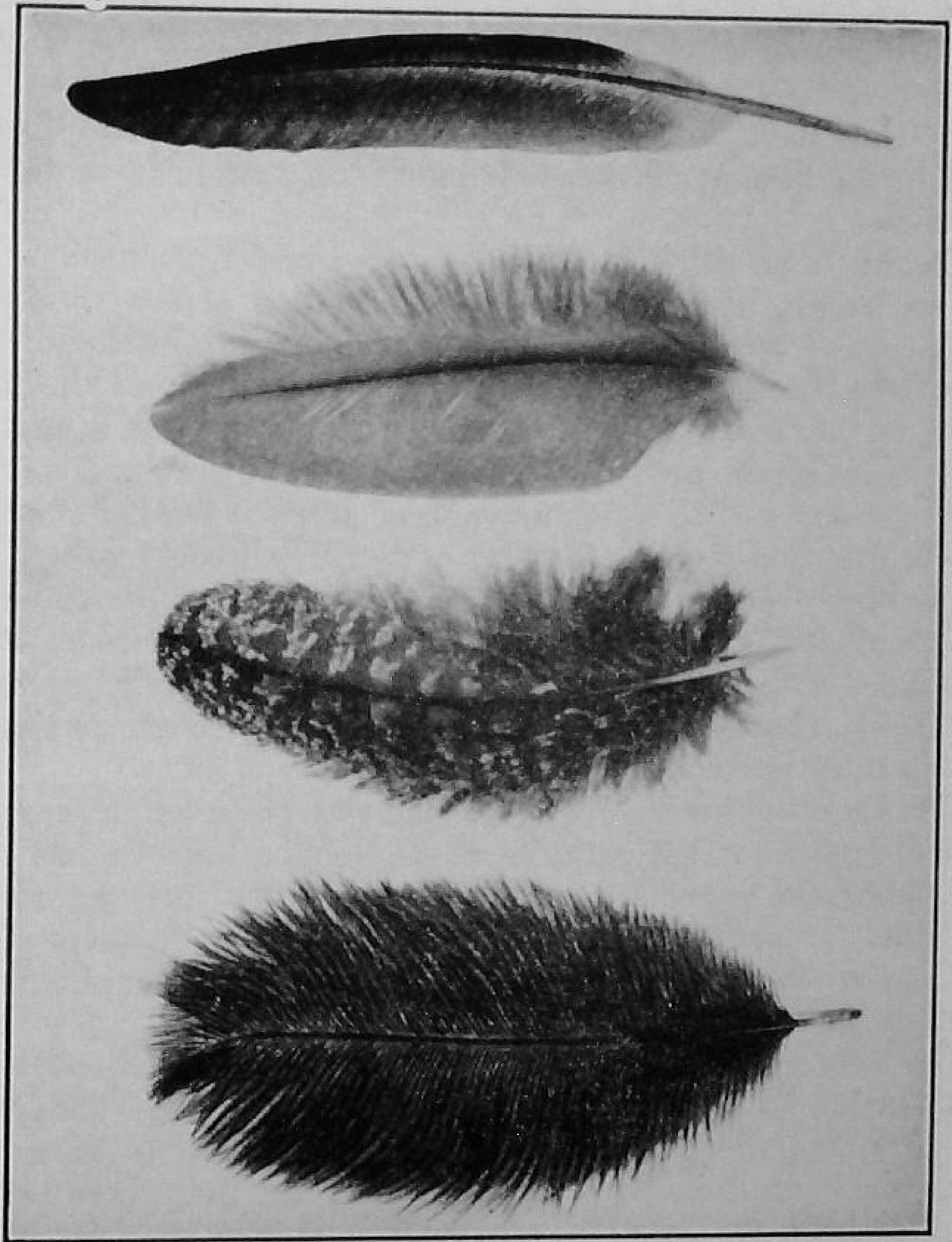


Fig. 19.—Different types of feathers. (*A*) Primary of Pigeon—an important flight feather with a stiff vane. (*B*) Under wing covert of a Great Blue Heron; downy portion overlapped by an adjoining feather. (*C*) Wing covert of Owl; the downy edge makes possible the all-important noiseless flight of this bird. (*D*) Feather of Ostrich; the power of flight has been lost, and the entire vane is downy. (*From "The Bird," by C. William Beebe; courtesy of Henry Holt and Company.*)

actually grow from the entire surface of the skin. In most species, including the fowl, the feathers are arranged in definite areas or feather tracts. Several of these tracts, or *pterylæ*, are paired, as may be seen readily by examining a picked carcass.

The parts of a typical body feather are the quill, which is continued throughout the vane of the feather as the shaft or rachis; the barbs, branching from the shaft; the barbules, branching from the barbs; and the barbicels, branching from the barbules. Except for size differences, most of the variation in the form and structure of feathers is due to differences in the mode of structure of the barbules and their branches.

The order of formation of the shaft of the feather is strictly apicobasal, and the order of age of the barbs is naturally the same. Similarly, in each barb, the apex at the margin of the feather is the first formed, and the central end attached to the shaft is the last. Thus there are two time gradients in each feather: from the apex to the base along the shaft, and from margin to center along the barbs.

The rate of growth of the shaft is approximately uniform throughout its length, at least during the formation of the vane of the feather. The rate of growth of the barbs, on the other hand, diminishes from the apex to the base of each, that is, from the margin of the feather to the shaft. This form of growth plays a large part in determining the pigmentation and general pattern of the feather. The time required to form the vane of a breast feather is approximately twenty days from the time of plucking an old feather.

The large feathers of the wings and tail are definite in number, and are molted and replaced, as a rule, in a regular order. As will be pointed out in the discussion of judging fowls for egg production, this fact can be used as a basis of estimating the length of time that certain birds have been out of production.

There are well-known differences between the sexes in the appearance of feathers in the neck, back, saddle, and tail sections. These are among the secondary sexual differences that are characteristic of birds. In certain "hen-feathered" breeds the feathers in these sections are essentially alike in both sexes. The Campine and the Sebright Bantam are examples.

The Skin.—A description of the skin and its specialized development in the form of comb, wattles and ear lobes, and the scales on the shanks and toes might easily be developed into an extended discussion. It is sufficient here to point out that there is a close relation between gonad development and activity, and the size and appearance of the comb and wattles. The practical application of this fact will be pointed out in the discussion of judging fowls for egg production.

The several different shank colors found in fowls result from dif-

ferent combinations of pigments in the upper and lower layers of skin.

Yellow shanks are due to the presence of lipochrome pigment in the epidermis, with the absence of melanic pigment. Black and its variations depend upon the presence of melanic pigment in the epidermis. It is probable that the darkest type of shank occurs when melanic pigment is present in both the dermis and the epidermis. Yellow in the dermis is obscured by black in the epidermis.

Blue, or slaty blue shanks occur when melanic pigment is present in the dermis, and neither type of pigment is pre-ent in the epidermis. With black in the dermis and yellow in the overlying epidermis, the shank appears willow green in color. White shanks are the result of complete absence of both types of pigment.

The Skeleton.—The skeleton of the fowl is compact, light in weight, and very strong. Many of the long bones are hollow, which helps to make them light; and many of them are fused together forming very strong structures to which the large muscles used in flight are attached. The keeled sternum is characteristic of the superorder *Neognathæ*, to which the domestic fowl belongs.

Questions are often asked about the rumpless fowls that sometimes are found in flocks of otherwise normal specimens. This condition may be either hereditary or accidental. In either case it is due to the absence of the last few vertebræ, including the pygostyle.

The Muscles.—The particular point of interest about the muscular system of the bird is the special development of the large muscles of the breast region. The greater part of this muscle group appears to be on the body proper because of the extensive attachment to the sternum. The muscles in this region weigh about as much as do all the rest of the muscles together, and make up about one-twelfth of the weight of the entire body.

The Respiratory System.—The respiratory system of birds is quite different from that of mammals. The lungs are firmly attached to the thoracic wall, and the active part of respiration is expiration. In mammals the more vigorous part of breathing is inspiration.

Connected with the lungs are four pairs of air sacs placed on either side of the body, and ranging in position from the neck to the abdomen, with a single median sac located in the cavity of the thorax. Besides opening into the lungs, these sacs communicate directly with the cavities of most of the bones of the body, with the exception of those of the forearm and hand of the wing and those below the hock-joint of the leg.

The voice of the fowl is produced in the syrinx, or lower larynx, located where the trachea divides into the two bronchi. The syrinx is the only part of the respiratory tract that is capable of producing sound, the upper larynx serving only to modulate the voice. The

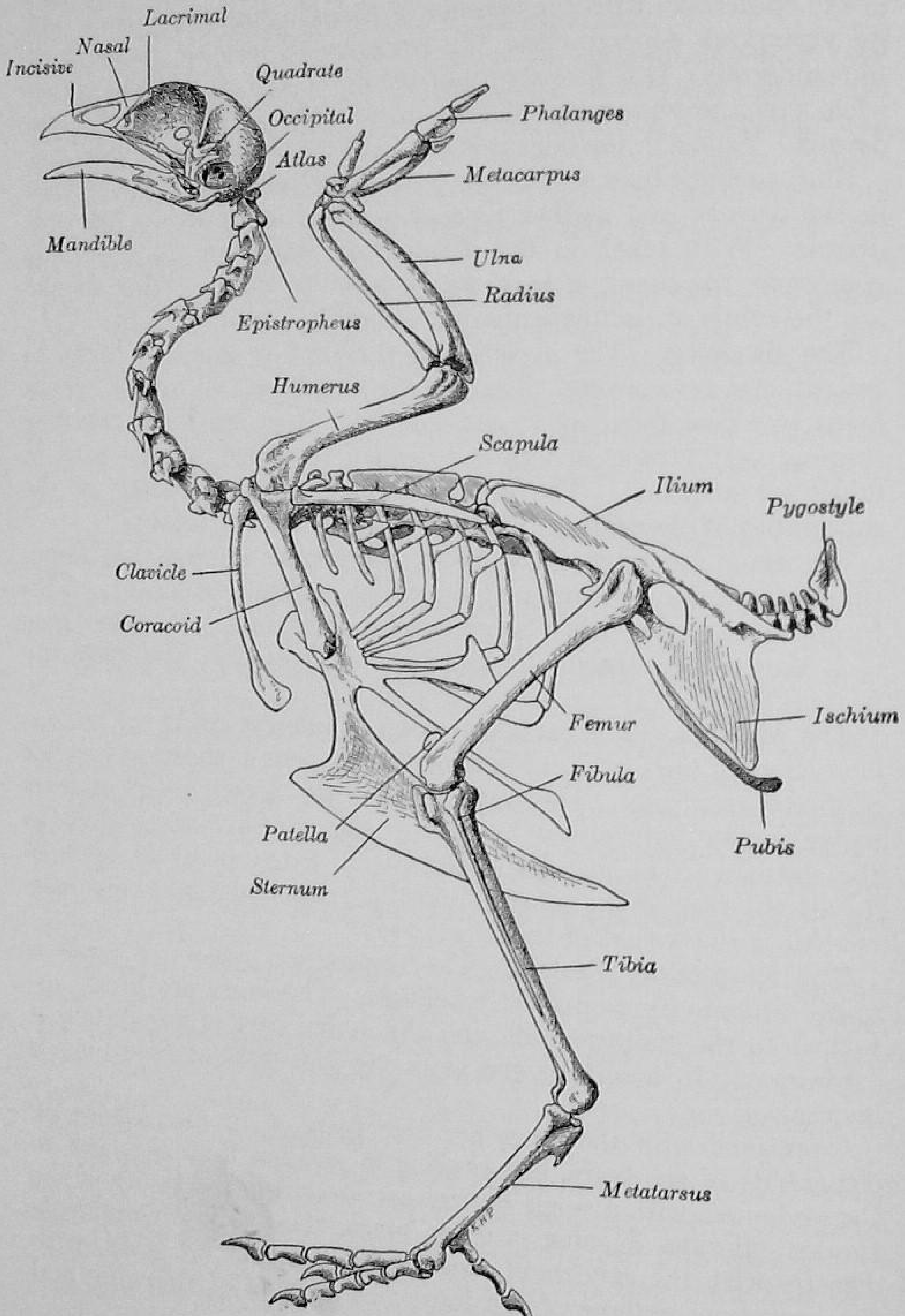


Fig. 20.—The skeleton of a fowl.

syrinx is essentially the same in both male and female. The normal hen does not crow because she lacks the psychological incentive to do so. If this incentive is provided experimentally, by suitable injections of the male sex hormone, hens so treated will crow.

The Digestive System.—The structure of the alimentary canal of the bird suggests that the digestive process is rapid and that it resembles both the carnivora and herbivora in certain particulars.

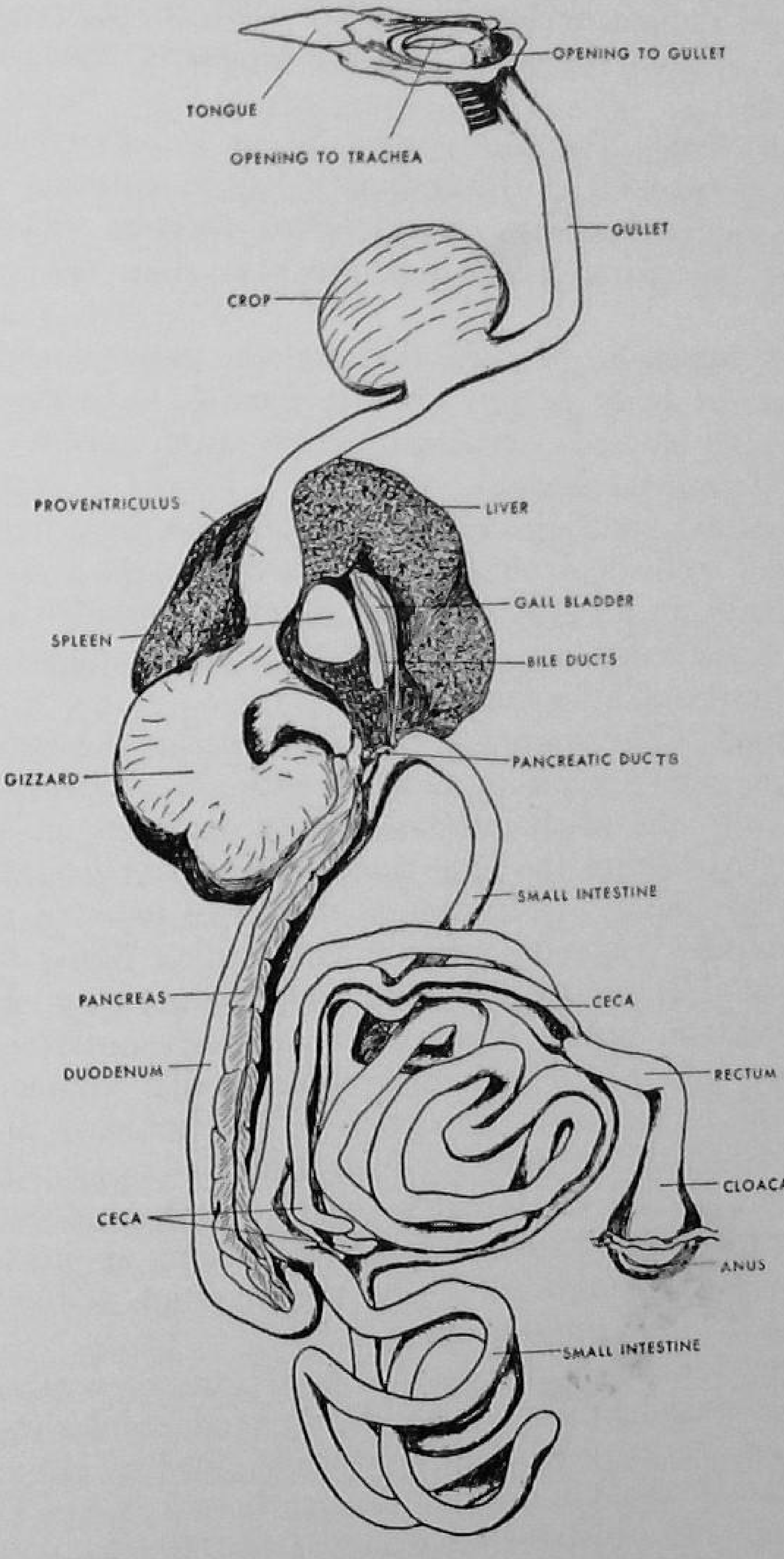


Fig. 21.—The digestive system of the fowl. *(Courtesy of F. B. Adamstone.)*

The relative shortness in length is a carnivorous characteristic, while the thorough pulverizing of the feed in the gizzard corresponds to mastication in the herbivora.

Mouth Parts.—The distinctive character of the mouth of the bird is the absence of lips and teeth. These parts are replaced by a horny mandible on each jaw, forming the beak.

The tongue in fowls and turkeys is shaped like the barbed head of an arrow with the point directed forward. The barb-like projections at the back of the tongue serve the purpose of forcing the grain toward the entrance to the gullet when the tongue is moved from front to back. In water fowl the tongue is wider, softer and more flexible.

Gullet and Crop.—The gullet or esophagus is distinguished by its enormous expansibility. Immediately before entering the body cavity it is enlarged to form a pouch called the crop, which acts as a storage for the coarse feed eaten, much as does the paunch of ruminants.

Glandular Stomach.—Beyond the crop the gullet contracts until well within the body cavity, when it expands somewhat to form the glandular stomach (proventriculus), from which it passes immediately into the gizzard.

The glandular stomach, which is little more than a thickening of the gullet wall, does not appreciably detain the feed, but surrounds it with an acid gastric juice which passes with it into the gizzard. Gastric digestion continues through the duodenum until inhibited by the alkaline bile.

The Gizzard.—The gizzard is oval in form, having two openings on its upper side, one communicating with the proventriculus and the other with the small intestine. It is depressed on each side, being situated behind the liver and partly covered by the lateral lobes of that gland. It is composed of two pairs of red, thick, powerful muscles covered internally with a thick, horny epithelium.

The gizzard is normally without movement when it is in an empty condition, but it begins rhythmic movements as soon as food passes into it. The number of muscular contractions per unit of time increases in proportion to the hardness of the feed. When food is withheld until the fowls become hungry, the proventriculus and gizzard are found to be vigorously and continuously contracting, the usual rate of contraction being about 2.5 times a minute for the fasting fowl. After the ingestion of food this rate increases to about 3 times a minute.

The chief function of the gizzard is to grind or crush the coarse feed. This crushing process is absolutely necessary for the digestion of grains, and is most efficient only when aided by the presence of grit and gravel taken in through the mouth and always present in a normal bird. The gastric juice is incapable of digesting the cellulose walls of the grains and does not act until the grains are reduced by

the gizzard to a more or less homogeneous pulp. The constant action of the gizzard may be heard by holding a little chick that has been supplied with grit, to the ear.

The gizzard functions as a filter, in such a way that fine material enters the duodenum in about one minute after ingestion by a fowl that has been starved, while coarse material is retained much longer to be ground by the contractions of the gizzard. Grit normally leaves the gizzard only as a very fine ash.

Pancreas.—Immediately after its attachment to the gizzard the intestine is folded in a long loop called the duodenum, the sides of which are parallel and enclose the pancreas. The pancreas plays a very important part in the work of digestion, and is relatively longer in birds than in mammals. It secretes a fluid known as the pancreatic juice, that contains proteolytic, amylolytic and lipolytic enzymes which vigorously hydrolyze proteoses, peptones, starches and fats. The pancreatic juice empties into the duodenum just anterior to the bile ducts.

Liver.—Two ducts convey the bile from the liver to the terminal part of the duodenum. The one from the right lobe of the liver is enlarged to form the gall-bladder in which the bile is temporarily stored. The one from the left lobe has no such enlargement. They enter the duodenum together, the cystic duct from the right lobe being slightly posterior to the other.

Intestine.—The walls of the small intestine secrete the intestinal juice, which contains erepsin and sugar-splitting enzymes. Erepsin is an enzyme which carries to conclusion the work of digesting the proteins. The sugar-splitting enzymes have the power of converting disaccharides into simple sugars which can be assimilated by the body.

Besides its digestive function, the small intestine also acts as an organ of absorption, taking in the soluble nutrients and inorganic salts.

Ceca.—At the juncture of the intestine and the rectum are two blind pouches, given off from either side, called ceca. These are usually 4 to 6 inches in length, and more or less completely filled with fecal matter. Their function is not fully understood, though it appears that they aid in the digestion of fiber.

Rectum and Cloaca.—The rectum terminates the digestive canal, being a short and somewhat enlarged continuation of the intestine. It opens into the cloaca, a chamber common to the digestive and genito-urinary passages, which opens externally at the vent.

The Urinary System.—Brief mention is made of the urinary system in order to point out that in birds the urine is discharged into the cloaca and excreted along with the feces. There is no liquid urine voided. The white, pasty material appearing in the droppings is largely uric acid, whereas the nitrogen in the urine of mammals is mainly in the form of urea.

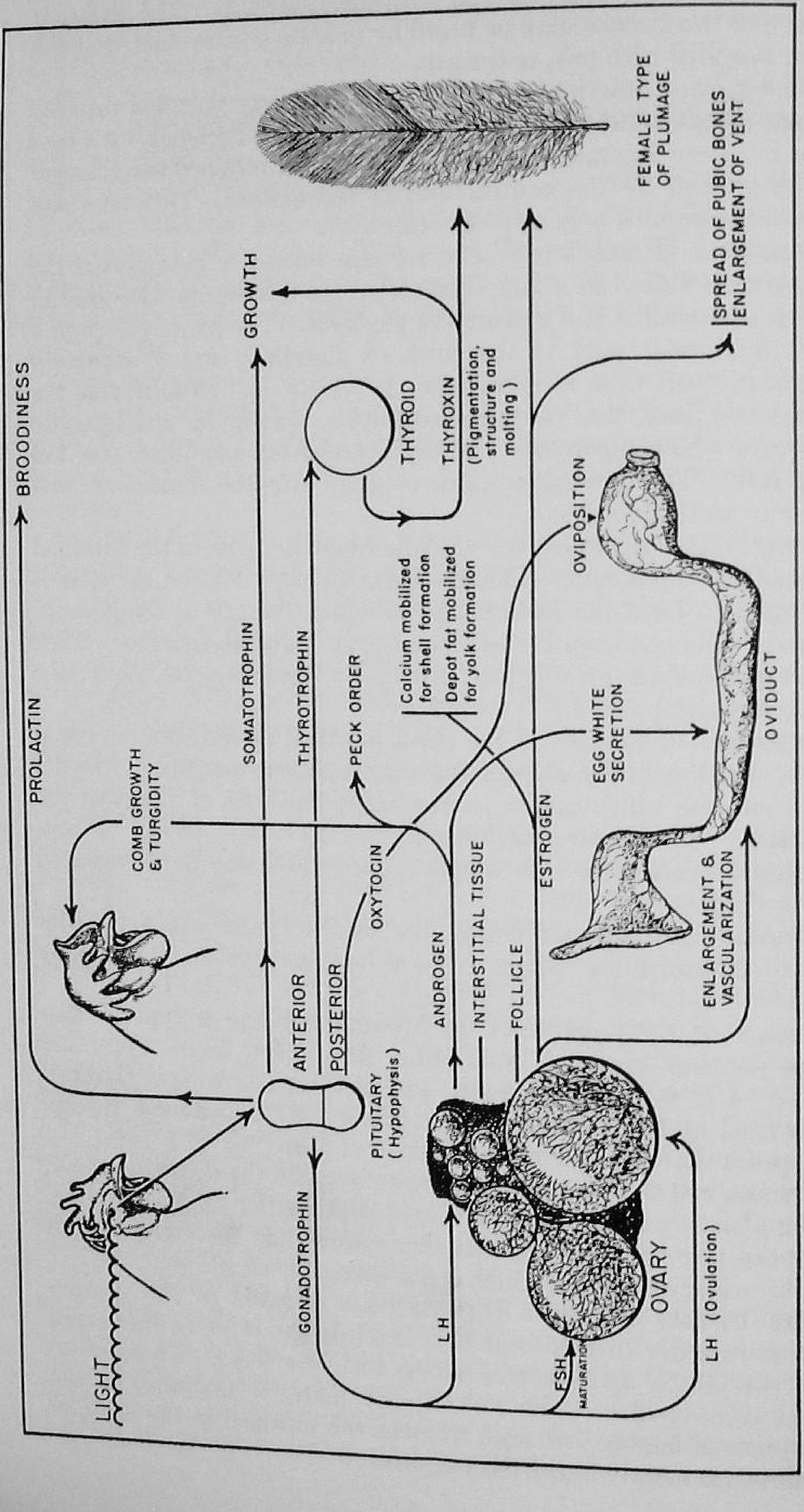


FIG. 22.—Diagram showing the principal effects of endocrine secretions, and their inter-relationships, in the female fowl. For adrenal effects, see Figure 23.

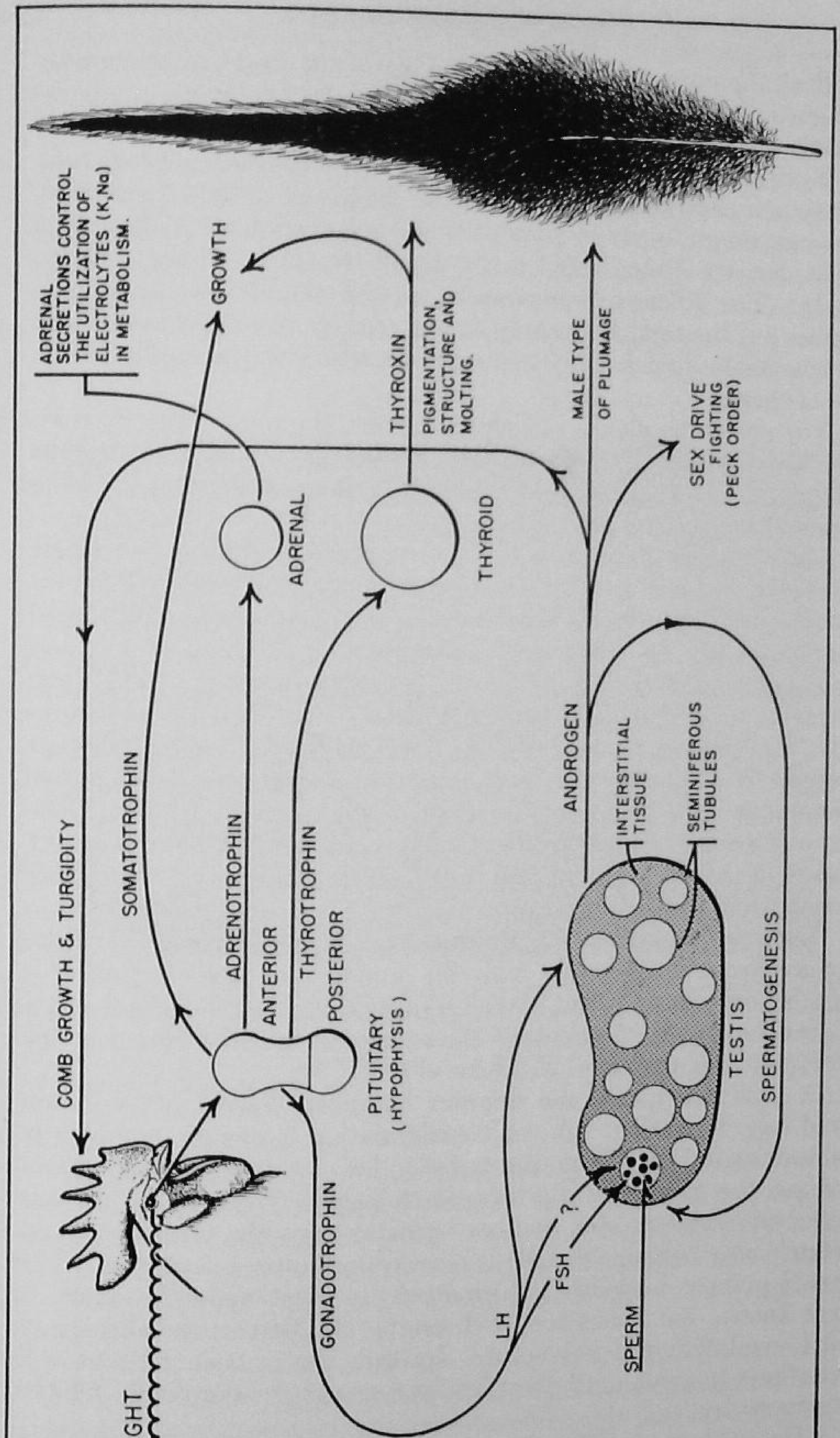


FIG. 23.—Diagram showing the principal effects of endocrine secretions, and their inter-relationships, in the male fowl.

THE ENDOCRINE GLANDS

Both the appearance and functioning of the fowl are profoundly affected by the secretions of the endocrine glands. These comparatively small but extremely important bodies, sometimes referred to collectively as the regulatory system, merit special consideration. They are described as endocrine, or glands of internal secretion, because the products of their cells are not carried away through a duct, but are disseminated in the blood stream to all parts of the body. The different secretions of specific glands have their own names but the term *hormone* (meaning rousing, or setting in motion) is commonly used for any endocrine secretion and is applicable to all of them.

The endocrine glands include the testes, the ovary, the thyroid, the parathyroids, the hypophysis or pituitary gland, the thymus glands, the adrenal or suprarenal glands, the pineal gland, and the islets of Langerhans.

Some of these glands are thus far known to produce only a single hormone, but one of them produces as many as five or six different kinds and it is probable that, as their study progresses, additional hormones will be discovered. Abnormal functioning of a gland may result in production of a hormone either in excessive amounts, or, more usually, in subnormal quantities. Both of these conditions give some idea of the effects of the hormone in question and for that reason they are frequently induced in experiments seeking to determine more about the functions of the endocrine glands. The usual procedure in such work is either to remove all or part of the particular gland being studied, or to add in some way an excessive amount of its active principle.

Hormone Control of Egg Production.—There are very few endocrine effects which result from the simple and direct action of a single hormone. Instead, the physiological and psychological activity of the chicken, particularly the female, is dependent upon a very complex interrelation of glandular effects.

A good example is the complex hormonal control of ovulation and egg formation. A follicle-stimulating hormone (commonly abbreviated FSH) from the anterior lobe of the pituitary gland causes the growth of the ovarian follicles. When a follicle has reached ovulatory size, another hormone from the pituitary gland (luteinizing hormone or LH) is released and causes ovulation. The exact manner in which LH produces its effect upon the ovary is not known, but it has been well established that in the absence of LH, ovulation will not occur. Instead, the ovarian follicles will continue to grow until they finally rupture, or completely fill the body cavity.

The oviduct also is under hormone control and it is stimulated, at exactly the right time, to pick up or engulf the released ovum.

Hormone secretions from the ovarian follicle are responsible for the enlargement of the oviduct to functioning size, for the spread of the pubic bones and enlargement of the vent, and for the mobilization of depot fat for yolk formation and of calcium for shell formation. Egg white secretion is apparently under the control of a hormone secreted by the ovarian interstitial tissue.

Formation of the egg shell is at least partially under the control of hormones secreted by the parathyroid glands and here also, timing—both as to the beginning and end of shell formation—is remarkably exact. And finally, a hormone from the posterior pituitary comes into play to cause the fully formed egg to be laid. The inter-relationships are shown diagrammatically in Figure 22.

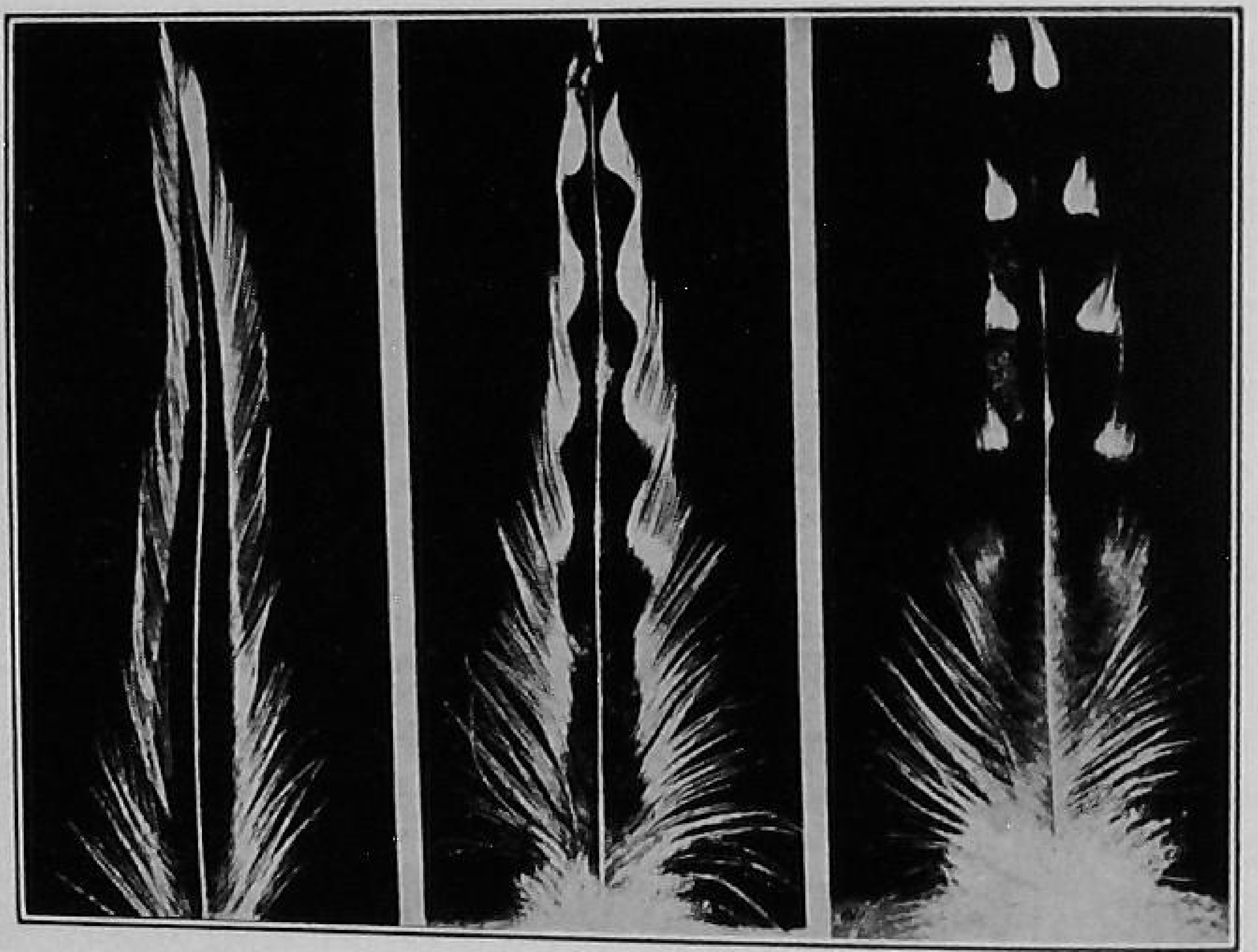
FIG. 24.—Sex dimorphism in structure of feathers. From left to right the paired male and female feathers are from the wing bow, neck and saddle regions. The male feathers (on the right in each pair) appear more pointed and lacier because of the large areas free from barbules toward the tip of the feathers. (*Photo by Dr. W. F. Lamoreaux, Cornell University.*)

Normal functioning of the whole process of egg production is completely dependent upon extremely fine adjustment and synchronization of all the foregoing events. If any gland begins to function "on its own," without awaiting the proper signal, such freaks as yolkless eggs, soft-shell eggs, and eggs within eggs are likely to result.

Not all of the known endocrine effects in the fowl are shown in Figures 22 and 23. The thyroid gland, for example, in addition to influencing body growth and feather formation, is partially responsible for more or less regular seasonal changes in egg production, body weight, and egg weight. The stimulus for this latter effect comes,

presumably, from the varying amount of light to which hens are subjected with the changing seasons, although the picture is complicated by the unfavorable effect of high air temperature on egg size.

One should also remember that not all of the postulated endocrine effects have been, or can be, so completely demonstrated as to leave no question in the mind of a skeptical reader. To prove conclusively that the hormone oxytocin, shown in Figure 22 as being responsible for oviposition, is in fact the only endocrine secretion which gives a hen the urge to seek a nest and lay an egg which has been fully formed, would require surgical techniques beyond those available at present.



a *b* *c*

FIG. 25.—Effects of thyroxin on color and structure of saddle feathers in Brown Leghorn males. *a*, Is normal; *b*, was injected with 1.0 mg. of thyroxin every seventh day; *c*, was injected with 1.5 mg. of thyroxin every sixth day. Extension of the black is accompanied by formation of barbules in the affected areas. (*After Lillie and Juhn in Physiol. Zoöl., Vol. 5.*)

If one could remove the posterior lobe of the pituitary gland without affecting the fowl in any other way, and if such a hen then formed normal eggs but laid them only after appropriate injections of oxytocin, the demonstration could be considered complete. Actually we know only that a large dose of oxytocin given intravenously will cause expulsion of a hard-shelled egg within 3 minutes. It seems reasonable to postulate that in the normal hen there is an accumulation of oxytocin sufficient to provide the necessary stimulus to laying.

Furthermore, the time of laying of a particular egg will be delayed one or more days if the follicle from which its yolk came is surgically

removed shortly after ovulation. Removal of other parts of the ovary has no such effect. The ruptured follicle may therefore be responsible either for the release of the necessary amount of oxytocin to cause normal egg laying to occur, or for the temporary removal of whatever mechanism is usually in effect to prevent premature laying.

Both egg laying and ovulation are also subject to the external influence of light and darkness. As will be pointed out in discussing the formation of the egg, ovulation normally occurs about thirty minutes after laying. But if laying happens to take place as late as 4:00 P.M., release of the next ovum does not occur until some ten or twelve hours later, unless the hen's normal lighting schedule has been reversed or she is being kept under continuous twenty-four-hour light of constant intensity. Hence no egg will be laid the following day.

Many poultrymen make practical use of this effect of light by subjecting non-laying hens to artificial illumination. This sets in motion a long train of activities or functions. Light stimulates the hypophysis to produce and secrete a gonadotrophic hormone which, in turn, activates the ovary.

Stimulation and growth of the ovary result in increased production of the ovarian secretions which, strangely enough, include both a male and a female sex hormone. The male sex hormone is responsible for the red, waxy comb and wattles of the normal laying hen, while the female sex hormone controls the typically feminine secondary sex characters such as normal female plumage, absence of spurs, and female sexual behavior.

If, as sometimes happens, a hen develops an ovarian tumor of sufficient size to destroy that part of her ovary which secretes the female hormone, she will gradually assume male characteristics. Her comb and wattles become large and coarse, her new plumage after a molt will be almost exactly like that of a male, and she may even crow.

Hormone Fattening.—Another example of a complex chain of events set in motion by the initial action of a single hormone, as well as of an application of endocrinology to practical poultry problems, is the chemical or hormone pseudo-caponization of cockerels. This involves the use of synthetic estrogens which are closely related to the female sex hormone.

A 15-milligram pellet of stilbestrol, implanted subcutaneously, will cause a remarkable change in the appearance of a Leghorn cockerel within ten to fifteen days. The comb loses its bright red color, and shrinks in size, until the cockerel resembles a capon in general appearance. What is more important, practically, is that there is an immediate increase in feed consumption, accompanied by a greatly increased deposition of fat. The same changes occur, of course, in any breed of chickens. The Leghorn is mentioned simply

because the comb changes are more striking than in breeds with smaller combs.

The greater deposition of fat cannot be completely explained at present, but it seems to be due to the demonstrated ability of estrogens to cause an increase in the amount of fat circulating in the blood stream, an effect which is known to occur in the laying hen as a result of normal secretion of the female sex hormone.

The pseudo-caponizing effect of estrogens, on the other hand, is fairly well understood. The estrogen—in this case stilbestrol—has an inhibiting effect on the pituitary gland, thus shutting off the normal secretion of the gonadotrophic hormones. Lack of these

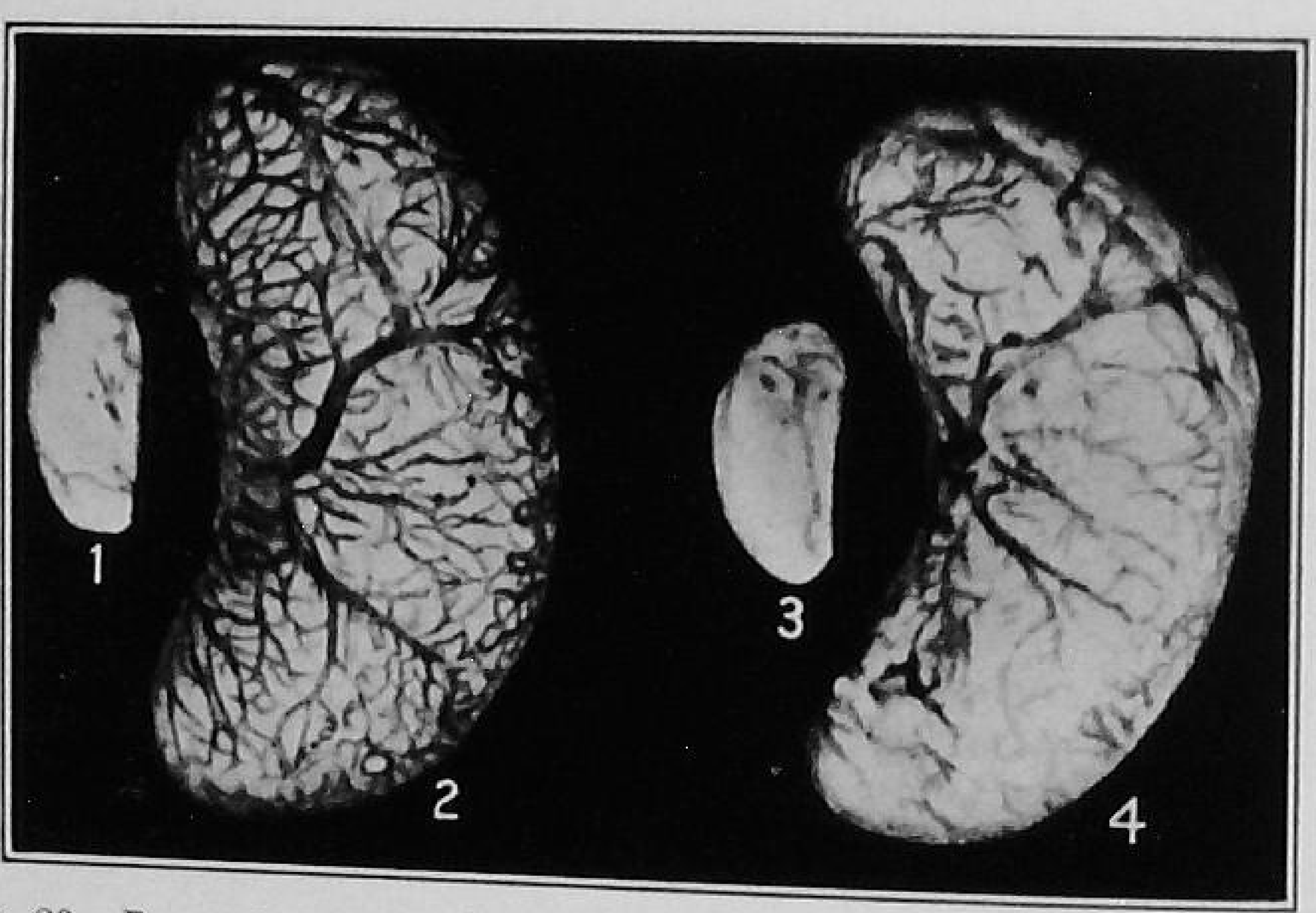


FIG. 26.—Regression of the testis in the absence of the gonadotrophic hormone in drakes. *Nos. 2 and 4:* left testes weighing 12.8 and 15.8 grams when removed at the time of hypophysectomy; *Nos. 1 and 3:* right testes weighing 0.6 gram when removed, respectively, twenty-one and fourteen days later. The regression occurred in spite of fourteen hours daily exposure to artificial light. (*After Benoit in Bull. biol. France et Belgique, Vol. 71.*)

will cause the testes to decrease in size, and will deprive them of the stimulus to secrete the male sex hormone, testosterone. Lack of testosterone will, in turn, result in regression of the secondary sex characters (comb, wattles, ear lobes, mating instinct, and crowing) because of the absence of endocrine encouragement. In time, the "maleness" is so completely submerged by the effect of estrogen, that the pubic bones are spread as in a laying hen, the skin over the abdomen becomes soft and velvety, and the coarse feather follicles characteristic of the adult male are no longer evident.

A secondary effect, not yet fully explained, is interference with calcium metabolism to such an extent that the long bones become brittle and very easily broken. Results similar to those following implantation have been obtained by feeding appropriate amounts

of synthetic products such as the dimethyl ether of diethylstilbestrol.

Soon after estrogen treatment is stopped, the pituitary gland recovers its ability to function normally, gonadotrophic hormones are again secreted, the testes increase in size and begin to secrete testosterone, and the secondary sex characters reappear in a short time.

Other Endocrine Effects.—Several other endocrine effects in the fowl have been well established. The feeding of large doses of either fresh or desiccated thyroid, for example, is followed by rapid molting. It has been shown that the thyroid gland increases in size during that portion of the year when molting normally occurs. Thyroxin, the active principle secreted by the thyroid, also affects the color and form of feathers.

Prolactin, secreted by the anterior lobe of the hypophysis, and so named because it induces milk secretion in mammals, is the controlling factor in broodiness in the fowl. Not only do laying hens, when dosed with prolactin, stop laying and quickly become broody, but male birds given sufficiently high doses likewise become broody, and will brood chicks just like a normal broody hen. The effect disappears quickly when injections of prolactin are stopped, and within a very few days such males are likely to kill the chicks which they previously cared for and defended.

Secretions of the adrenal glands are concerned in metabolism of carbohydrates and of sodium and potassium, and in the regulation of blood-pressure. Hormones secreted by the islets of Langerhans, which are scattered through the pancreas, presumably control the level of blood sugar in the fowl as in mammals.

Many other endocrine effects are being studied experimentally, and new information is constantly being brought to light. More and more of the hormones are being prepared synthetically, as their chemical nature is determined. The sex hormones are related to the fats, whereas all the others are protein in nature. Certain protein compounds have been found to have effects which are very similar to those brought about by the natural hormones. Thyroprotein, for example, has a thyroxin effect, whereas thiouracil has an opposite effect. Experiments already carried out suggest that it may eventually be possible to control growth, fattening, and reproduction in the fowl to a much greater extent than at present, largely through the administration of synthetic hormones.

Furthermore, some knowledge and understanding of the principal hormones is important in the practice of selection for physiological characters. Success in selection which is aimed at improving winter egg production when artificial lights are not used depends on being able to identify, by their performance, individuals which have a naturally high rate of secretion in respect to the gonadotrophic hormone which stimulates ovarian activity. Non-broody hens, and presumably males, which do not transmit broodiness to their daughters are those which have an inherently low secretion rate for pro-

lactin—the hormone which causes broody behavior. Selection for the ability to fatten easily and quickly may well depend on the extent to which one is able to identify, albeit by indirect means, those individuals which have a higher than average level of estrogen secretion.

REPRODUCTION AND THE FORMATION OF THE EGG

The Reproductive System of the Male.—The male fowl possesses two testes which are situated high up in the abdominal cavity, along the back, near the anterior ends of the kidneys. These never descend into an external scrotum, as is the case with other farm animals. In form they are more or less ellipsoid, and in color light yellow, frequently having a reddish cast caused by the numerous much-branched blood-vessels on the surface.

In gross structure the testis consists of a large number of very slender, much-convoluted ducts, from the linings of which the sperm are given off. These ducts, called seminiferous tubules, appear in groups separated by delicate membranes which extend inward from a membrane surrounding the organ. They all lead eventually to the vas deferens, a tube which conducts the sperm outside the body.

Each vas deferens opens into a small papilla, which serves as an intromittent organ. These are located on the dorsal wall of the cloaca. The so-called rudimentary copulatory organ of the fowl has no connection with the vasa deferentia, and is located on the median ventral portion of one of the transverse folds of the cloaca. It is this rudimentary organ, or male process, which is used in the classification of baby chicks according to sex on the basis of cloacal examination.

The Reproductive System of the Female.—In early embryonic life there are two gonads in the female, as in the male. Normally, only the left one develops, the right persisting, if at all, only as a functionless rudiment. A few cases have been reported, however, in which both a right and left ovary and oviduct were present and functioning in a mature pullet.

The functioning ovary appears as a cluster of many spheres, each of which is independently attached by a very slender stalk. Each sphere is a more or less developed ovum or yolk enclosed in a thin membrane or follicle. The spheres vary in color from pale straw color to deep reddish-yellow or orange, and in size from that of a mature yolk about 40 mm. in diameter down to those so small as not to be visible to the unaided eye.

In counts of the total number of ova and ruptured follicles visible to the unaided eye it was found that they varied in number from about 900 to over 3600. There did not appear to be any correlation between the total number counted and previous trapnest records

of the hens, but when chickens, waterfowl and certain wild birds are compared, the mean number of visible oöcytes of *different kinds of birds* reflects the normal fecundity or laying activity of the same kinds of birds.

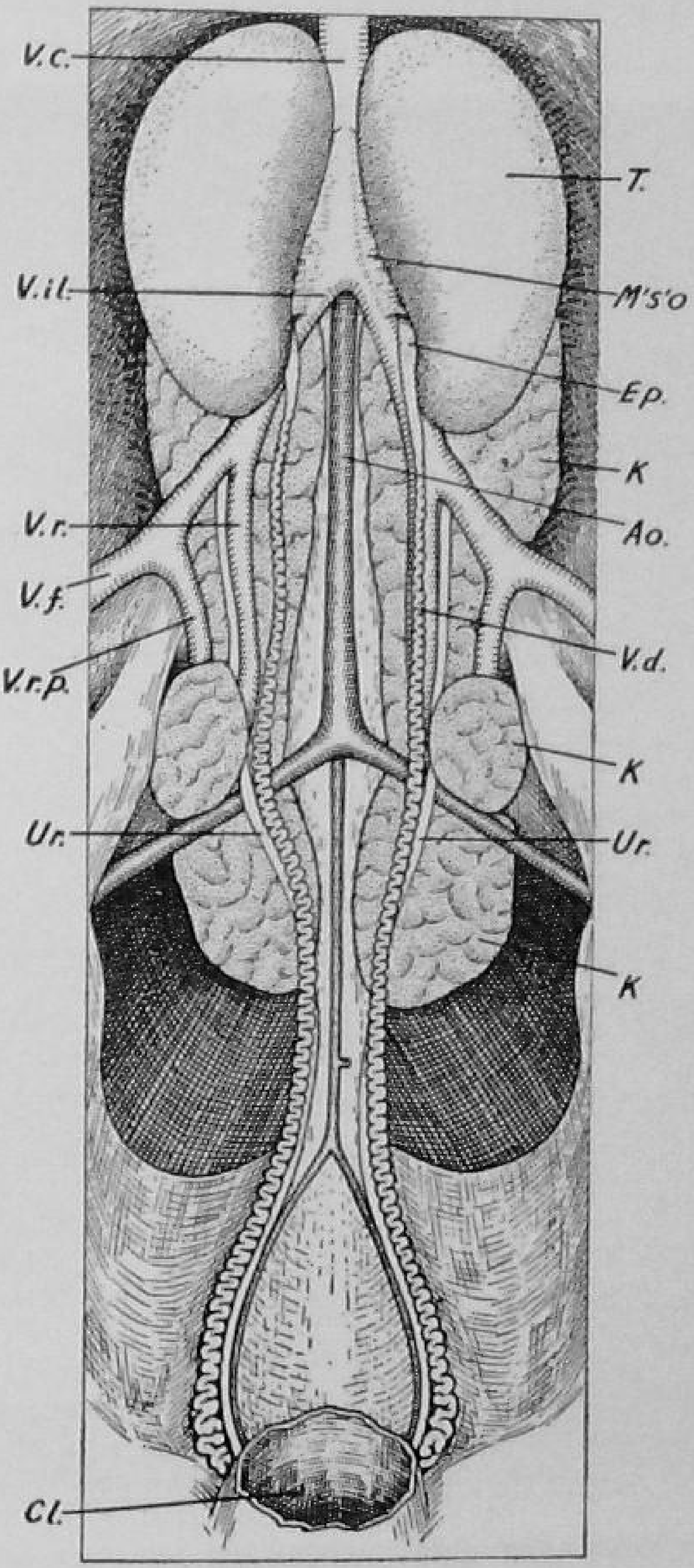


FIG. 27.—The reproductive and urinary organs of the male fowl: *T.*, testis; *V.d.*, vas deferens; *K.*, kidney; *Ur.*, ureter; *Cl.*, cloaca. *(Courtesy of L. V. Domm.)*

Removal of a part of the ovary is followed by prompt regeneration until the gonad is restored to its usual or normal size for the individual. It has sometimes been suggested that this regeneration is accompanied by increased ovulation so that the end-result of partial ovariotomy is greater egg production, but carefully controlled experiments have shown that no such relationship exists. The effects of partial ovariotomy of White Leghorn pullets at eight

weeks of age were "deleterious in some cases, harmless in others, but beneficial or stimulatory in none." Scarifying or mutilating the ovaries of fowls that had once been very good layers, but that had become low producers as they grew older, had no effect on their subsequent production.

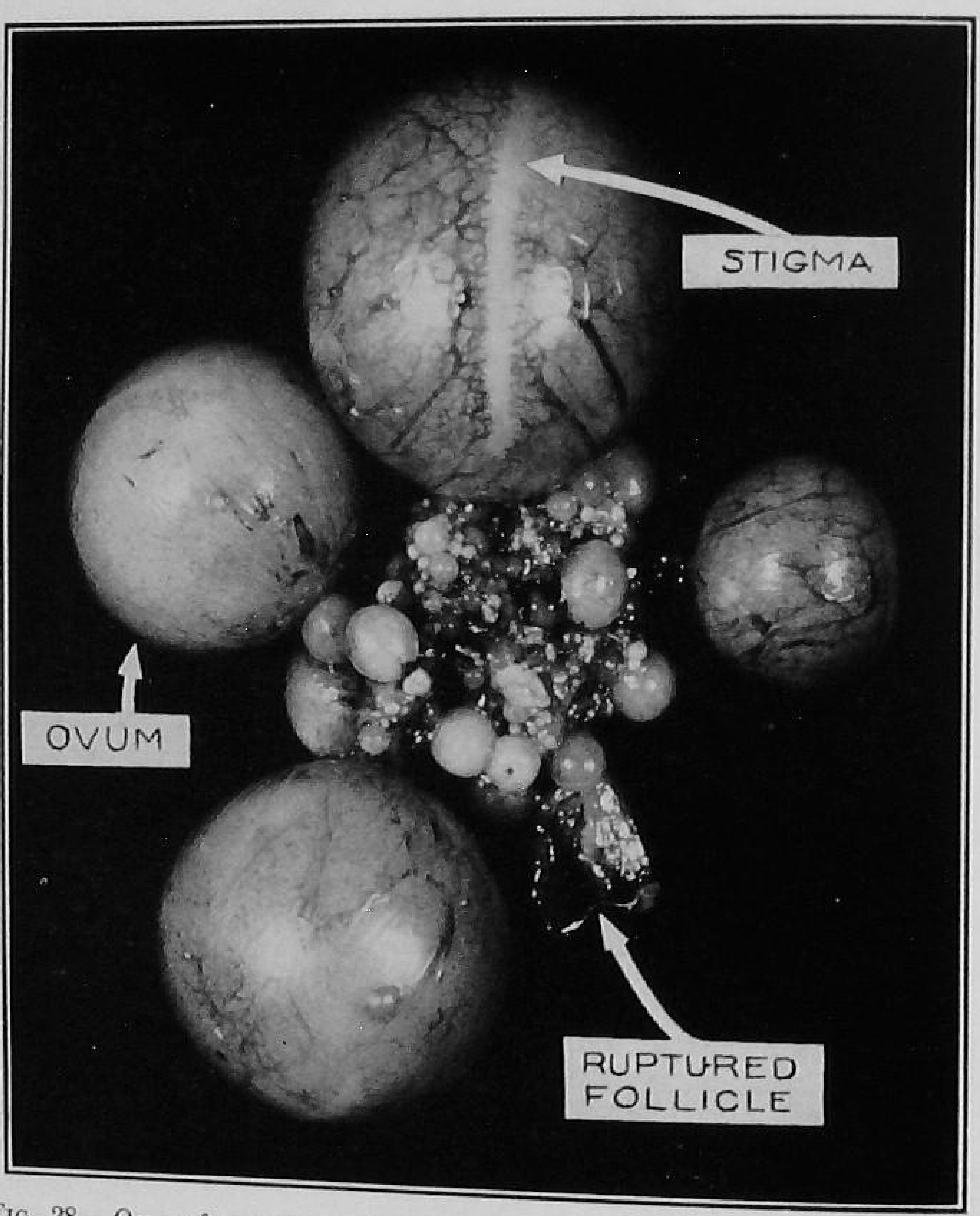


FIG. 28.—Ovary from a hen in laying condition, showing ova of various sizes and a ruptured follicle from which an ovum was recently released. (*Courtesy of Cornell University.*)

The Oviduct.—Associated with the ovary, and corresponding to the vas deferens of the male in certain functions, though having quite a different origin and developmental history, is the oviduct. In a laying hen the oviduct appears as a large, much-coiled tube occupying a large part of the left side of the abdominal cavity. It is covered with a net-work of blood-vessels, and is in more or less continuous movement during the time that an egg is being formed.

The oviduct is divided into five rather clearly defined regions.

Beginning at the end nearest the ovary, these are: (1) the funnel or infundibulum; (2) the magnum, where the thick white is secreted; (3) the isthmus, which secretes the shell membranes; (4) the uterus or shell gland; and (5) the vagina, which leads into the cloaca.

The Formation of the Egg.—The egg of commerce consists of the true egg, or reproductive cell, *i. e.*, the yolk with its germinal disc, and the surrounding envelopes of white, shell membranes and shell. The yolk is formed in the ovary, but the balance of the process occurs in the oviduct.

Formation of the Yolk.—During the early stages of yolk formation, the oöcytes grow very slowly by the gradual accumulation of light yolk. When a diameter of about 6 mm. is reached, certain ova, but only a few at any one time, suddenly begin to grow at an enormously increased rate. They add about 4 mm. to their diameter

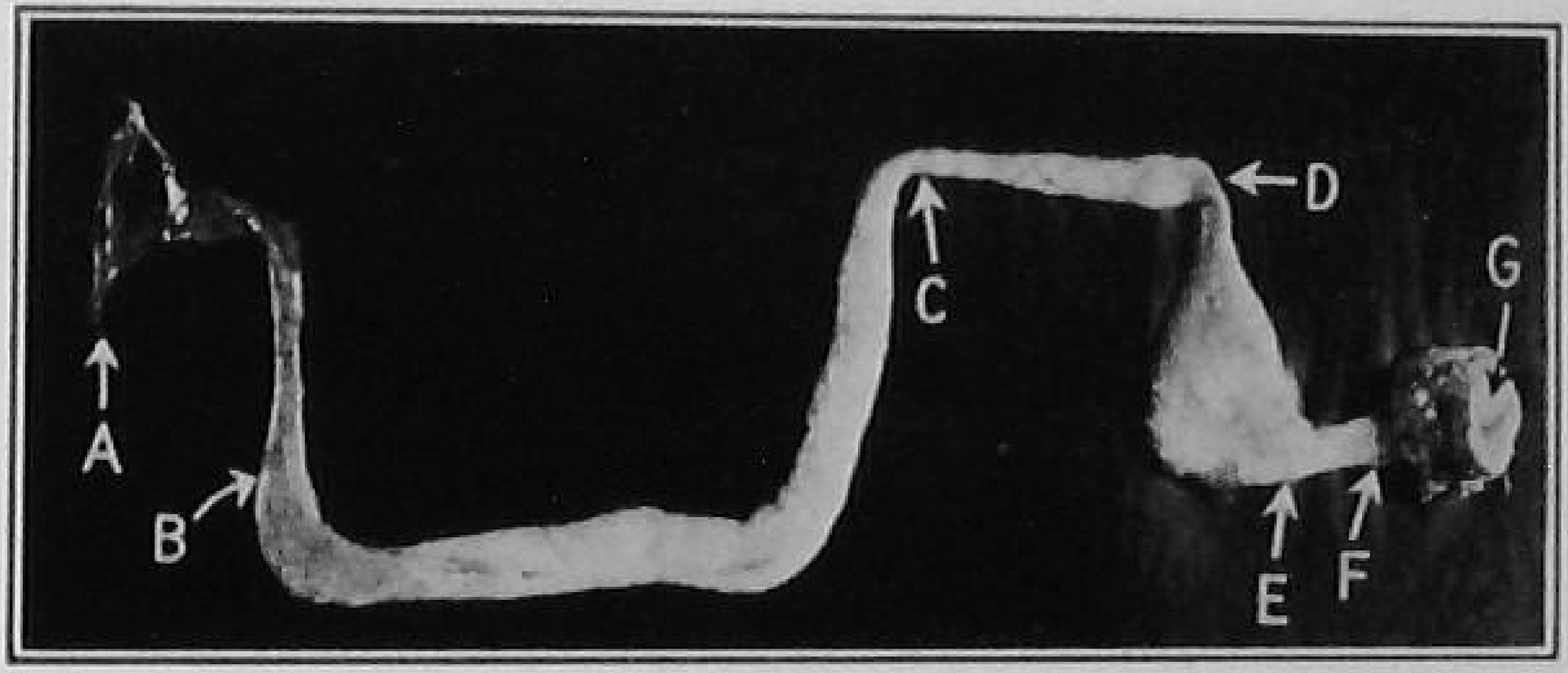


FIG. 29.—The oviduct of the hen. *A-B*, infundibulum; *B-C*, magnum; *C-D*, isthmus; *D-E*, uterus; *E-F*, vagina; *G*, cloaca. (*After Scott.*)

every twenty-four hours, until full size of about 40 mm. in diameter is reached. An ovum within seven to nine days of laying contains less than 1 per cent of its final complement of yolk, yet those few days suffice to supply the missing 99 parts.

It is during this period of rapid growth that the concentric layers of light and dark yolk are formed. The thickness of each pair of light and dark layers, representing the growth in a twenty-four-hour period, is from 1.5 to 2 mm. The visible white and yellow bands result from periodic deposition of differing amounts of carotinoid pigment. Although yolk deposition continues at a nearly constant rate throughout the twenty-four-hour day, that formed at certain periods is light in color because no dietary pigment is available.

As the yolk enlarges, the germinal disc remains on the surface, and thus leaves behind a trail of white yolk which forms the neck of the flask-shaped mass of white yolk which is a part of every normal egg.

Ovulation.—When the yolk comes to full size it is released from the ovary by the rupture of the follicle along the stigma. In most

instances the ovum probably is discharged into the body cavity and is later engulfed by the funnel of the oviduct through repeated advances and recessions of the edge of the infundibulum over the surface of the ovum. Once completely enclosed, it appears to be forced along by wave-like contractions of the muscles of the oviduct.

Fertilization of the Egg.—Fertilization follows almost immediately after ovulation, the spermatozoa having made their way through the entire length of the oviduct after mating has occurred.

Since the sperm must penetrate the vitelline membrane, which surrounds the yolk, in order to reach the germinal disc, it is of interest to point out that the true vitelline membrane on the freshly ovulated yolk has been found to be only 4 microns thick. After a short time in the oviduct, the membrane becomes swollen and thickened, as a result of contact with the secretions of the oviduct. It is also augmented by mucin secretions which thicken and strengthen it as a protection against rupture of the yolk. The complete vitelline membrane from the yolk of a laid egg is about 48 microns thick.

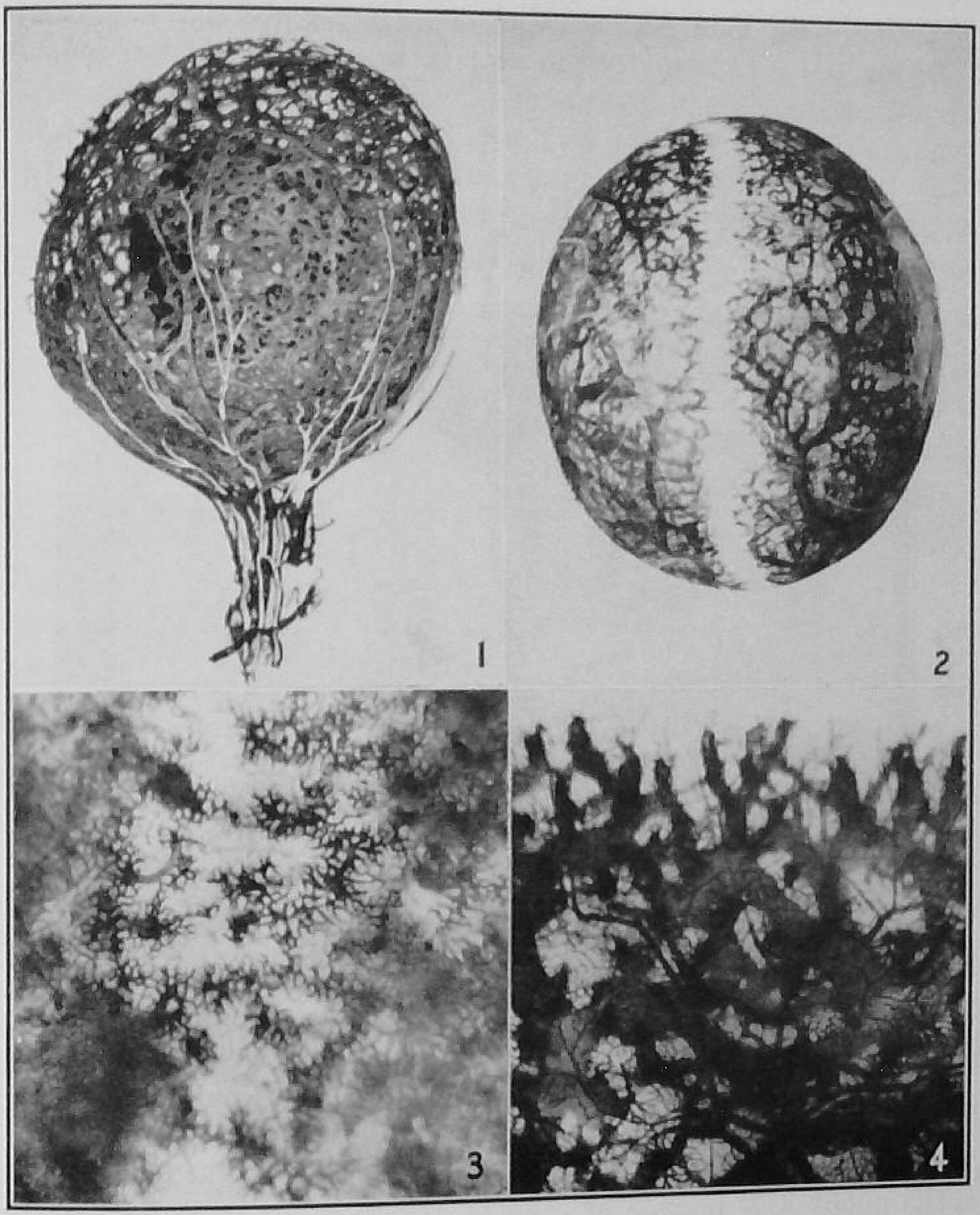
Secretion of the Dense White.—During its passage through the magnum, or albumen-secreting region, the yolk acquires the mass of firm white which makes up about one-half of the total white, by volume. The remainder of the white is not added until after the shell membranes have been formed and the egg has entered the uterus. It has been shown by analyses of egg white at different stages of egg formation that this latter addition is largely water and that no nitrogen is added to the egg in the uterus.

Formation of the Shell Membranes.—The shell membranes are formed in the isthmus. It is an interesting fact that these membranes should be so formed as to enclose the yolk and thick white rather loosely. They do not plump out until the egg receives its final quota of white in the uterus.

Formation of the Chalazæ.—The two whitish cords, known as chalazæ, which extend out from the yolk toward the ends of the egg, though obviously formed from material secreted in the upper part of the oviduct, do not become visible until after the egg has entered the uterus. Their formation appears to be partly the result of a change in the colloidal structure of the layer of white adjacent to the yolk, and partly the result of rotation of the white around the yolk while the egg is in the uterus. Chalaza formation has been artificially induced in eggs removed from the anterior portion of the uterus.

Formation of the Shell.—The shell of the hen's egg consists mostly of calcium carbonate, the reported percentages varying from 93 to 98. This material is deposited in the uterus, and there is considerable shell material deposited on the membranes before the egg has acquired its full quota of white.

PLATE I



VASCULAR SYSTEM OF THE OVARIAN FOLLICLE.
(After Nalbandov and James.)

1. Vinylite resin cast of the vascular system of a mature follicle and its stalk. Arteries white and veins dark.

2. Injected pre-ovulatory follicle. Note that no large blood vessels extend across the stigma.

3. View from inside a follicle showing that vascularization of the stigma consists primarily of a fine capillary network.

4. India ink injection of the vascular system of a pre-ovulatory follicle viewed from the inside. The stigma is at the upper edge of the picture.

The rate of shell deposition is relatively slow during the first three hours. It then increases rapidly until about the fifth hour, after which a constant rate is maintained until the twentieth hour (approximately the time of laying).

While the egg is in the hard-shell stage in the uterus it is possible to locate it by external palpation. This method can be used in keeping egg records except during the breeding season when pedigreeing is being done. At the Utah Station it was found that the whole flock could be handled early each morning and the individual hens which would lay during the day determined with accuracy.

FIG. 30.—A double-yolked egg, showing how the yolk is formed in concentric layers. The hen was fed a small amount of a fat-soluble dye (Sudan III) on each of five successive days. (*After Gage and Fish.*)

A 5-pound hen laying 300 eggs in a year must deposit in the egg shells about 3.75 pounds of calcium carbonate (1.5 pounds of calcium). Since this is about thirty times the amount of calcium in her entire body, it is obvious that such a hen must be supplied with an abundance of calcium in her feed.

There is considerable evidence to support the view that much of the calcium used in shell formation is first deposited in the long bones and that often no more than 10 to 40 per cent of the calcium in a particular egg comes directly from the feed. For short periods of time all of the calcium may come from the bones, as is normal in wild birds which lay only a few eggs. If, however, laying hens are suddenly deprived of all food calcium their eggs promptly show thin shells, and egg laying stops in ten to fourteen days. It seems entirely

possible that some of the complications which often accompany high egg production develop because some hens are unable to replace calcium in their bones as rapidly as it is withdrawn for shell formation.

Laying of the Egg.—Eggs are normally formed small end caudad, that is, with the small end first as they move down the oviduct. This is true of wild birds as well as of the fowl. But curiously enough, if the hen is not disturbed in the act of laying, most eggs are laid large end first. This has puzzled poultry workers for many years. Not until an English investigator made use of radiographic techniques and published his findings in 1951 was the series of events made clear.

TABLE 13.—THE APPROXIMATE LENGTH OF THE VARIOUS PARTS OF THE OVIDUCT AND THE TIME INTERVALS INVOLVED IN EGG FORMATION

Section of oviduct	*Approximate length in centimeters**	*Approximate time for the yolk to traverse each section†*
Infundibulum (and chalaziferous region)	11.0	¼ hr.
Magnum	33.6	3 "
Isthmus	10.6	1¼ "
Uterus	10.1	20¾ " (Uterus and Vagina)
Vagina	6.9	
Interval between laying and next ovulation	....	½ "

* Illinois data on 70 White Leghorns.
† Adapted from Warren and Scott (1935).

TABLE 14.—AVERAGE TIME SPENT IN DIFFERENT PARTS OF THE OVIDUCT BY EGGS REQUIRING VARIOUS PERIODS FOR THEIR FORMATION. (AFTER WARREN AND SCOTT, 1935.)

Item	*Hens with interval lengths of (hours)* 25	26	27	28	29	30
Time from laying of one egg to entrance of isthmus by next egg	4.3	4.6	4.2	4.7	5.2	5.3
Time spent in uterus	18.0	18.4	19.9	19.8	20.8	21.6
Time from first indication of shell to laying of the egg	13.8	14.7	15.6	16.4	17.0	17.9
Number of eggs observed	9	25	20	42	44	21

As can be seen in Plate II, the fully-formed egg is turned horizontally (not end-over-end) through 180 degrees just prior to laying. In order for this to happen the egg must drop from its normal position high up between the ischia to a point opposite the tips of the pubic bones. This is necessary because the normal egg is too long to turn in a horizontal plane within the pelvic arch. The position of an egg after it has turned and is ready to be laid is shown in

Figure 6 of Plate II. Rotation of the egg is accomplished in a matter of one to two minutes. Should the hen be disturbed as she raises herself slightly from the nest when the egg is about to turn, she is very likely to expel it immediately and in that event it will be laid small end first. There is also some variation among hens and no doubt among breeds in the consistency with which they lay eggs large end first. It is not known whether hereditary factors are involved.

No valid reason has been advanced for the fact that eggs are formed small end caudad. As for the reversal prior to laying, it seems reasonable to assume that muscular pressure required for expelling the egg is more effectively applied to the small end. The entire shell gland is everted with the egg and then withdrawn. Failure of normal withdrawal may sometimes lead to the condition known as prolapse.

Time Intervals in Egg Formation.—Careful observations made on anesthetized birds at the Kansas Agricultural Experiment Station, together with autopsy records of hens in laying condition, have made it possible to estimate with considerable accuracy the time required to form the various parts of the egg. These time intervals are summarized in Table 8, along with average lengths of the various parts of the oviduct as determined on 70 White Leghorn hens at the Illinois Station.

The time between laying and the next ovulation, as observed at the Kansas Station, ranged from fourteen to seventy-five minutes, and there is also some variation in the rate of passage through the

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Legend for Plate II

Radiographic Views of Egg Shell Formation in the Hen.
(*After Bradfield and Fozzard in the Journal of Experimental Biology, Vol. 28.*)

1. Radiograph of a hen taken 6½ hours after an egg had been laid. The new yolk has been surrounded by both the white and the shell membranes and has passed into the shell gland (uterus). The first faint outlines of the calcareous shell can barely be detected.

2. The same egg three hours later.

3. The same egg 12 hours after the previous egg had been laid.

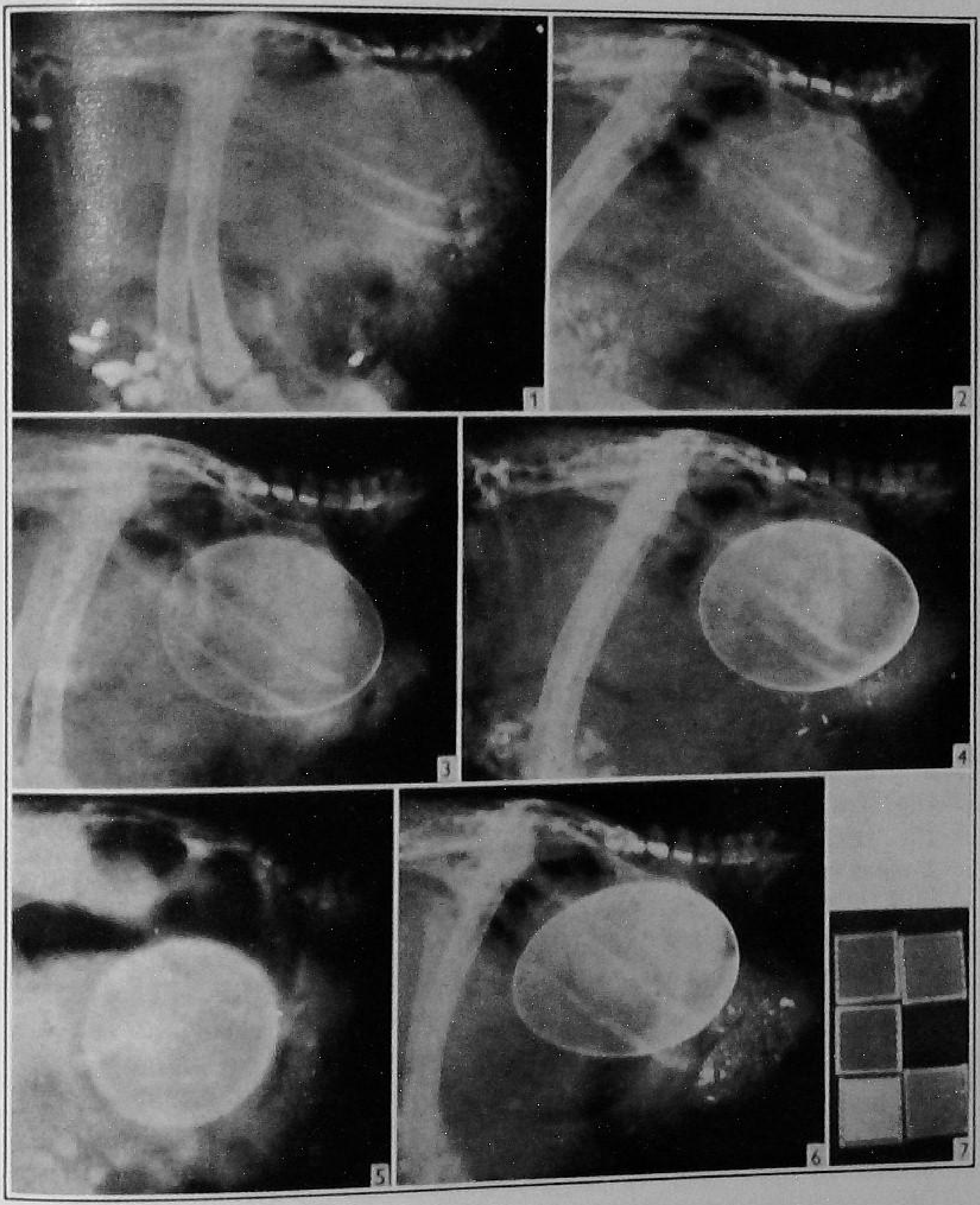
4. The same egg still later, 23½ hours after the previous egg had been laid. The gradual increase in shell thickness, as shown by *X*-ray absorption, is clearly evident.

5. A different egg which was observed at frequent intervals during the last few hours before it was due to be laid, so that the rotation could be followed. This radiograph was taken half way through the rotation, and the egg is therefore seen end-on. The picture was slightly blurred by the breathing movements of the hen. Note the lowered position of the egg in the body cavity. The time required for rotation is between one and two minutes.

6. The same egg shown in views 1, 2, 3 and 4, but 25½ hours after the previous egg had been laid, and ½ hour before it was itself laid. In the preceding views (1 to 4), the pointed end is caudad, but here the egg has rotated through 180° so as to bring the blunt end caudad.

7. Calcium carbonate suspensions used for comparison.

PLATE II



different sections of the oviduct. Hens which lay small clutches, with long intervals between eggs, and low intensity, also have long delays in ovulation. Poor production of low-intensity hens is caused not only by the longer period of egg formation but also by a longer delay in ovulation between clutches.

Records on 119 Rhode Island Red pullets for one year at the Massachusetts Station showed an average interval of 26.5 hours between successive eggs in the same clutch. The shortest interval observed for any one hen was 23 hours in April, and the longest was 31.7 hours in February. The average interval for all birds was shortest in April (25.7 hours) and longest in February (27.7 hours).

Shape, Size, and Color of Eggs.—The normal or characteristic shape of the egg is determined in the magnum, but the specific shape may be modified by abnormal or unusual conditions in either the isthmus or the uterus.

Eggs laid by a hen after the anterior half of her isthmus had been removed were, for the most part, more irregular in shape than eggs laid before the operation. In another hen the isthmus was torn longitudinally and then closed with catgut sutures. After the operation this hen laid eggs with characteristically wrinkled shells, suggesting that the specific shape of the shell membranes, as determined in the isthmus, has a direct influence on shell shape.

Operations on the uterus showed clearly that shape of the egg may also be affected by that portion of the oviduct. Eggs laid by a hen after cotton was placed at the sides of the uterus had a depression reaching more or less around the egg.

That there is great variability in the size of hens' eggs is well known, but the specific causes of this variation are not so well established. It is obvious that the weight of the egg is equal to the sum of the weights of its parts, and that anything affecting the weight of any of the parts may be expected to have some influence on the weight of the entire egg. The small size of the eggs laid by pullets at the beginning of the laying period is due in part to the smaller size of yolk in such eggs, as well as to the lesser amount of albumen. The shell is, of course, formed to fit the egg contents.

The position of an egg in the clutch affects its weight. The second egg of a two-egg clutch is nearly always smaller than the first egg, and in clutches of several eggs, the first egg is usually the heaviest with a progressive decrease in the weight of the egg laid on each successive day. This decrease is almost entirely the result of a decrease in the amount of white, since yolk size appears to be very nearly constant, for any given hen, for all clutch positions.

The color of eggs is in large measure a characteristic of individual hens, all eggs laid by a hen tending to be of the same color except for a gradual change from a darker to a lighter shade during a continuous period of daily laying.

The Completed Egg.—The gross parts of an egg are shown diagrammatically in Figure 31. Taking these in the order of their formation they are: (1) the germ spot, or blastoderm; (2) the yolk; (3) the white; (4) the shell membranes; and (5) the shell.

The Germ Spot.—The germ spot is closely associated with the yolk. Because its development can be traced back to a point where the cell of which it is a part is yolkless, that is, when no yolk material has been laid down, and also because of its importance as the living part of the egg, it is described separately. Technically it is referred to as the germinal disc in an infertile egg, or prior to fertilization, and as the blastoderm following fertilization, but before development has proceeded very far. It later gives rise to an embryo which ultimately becomes a chick.

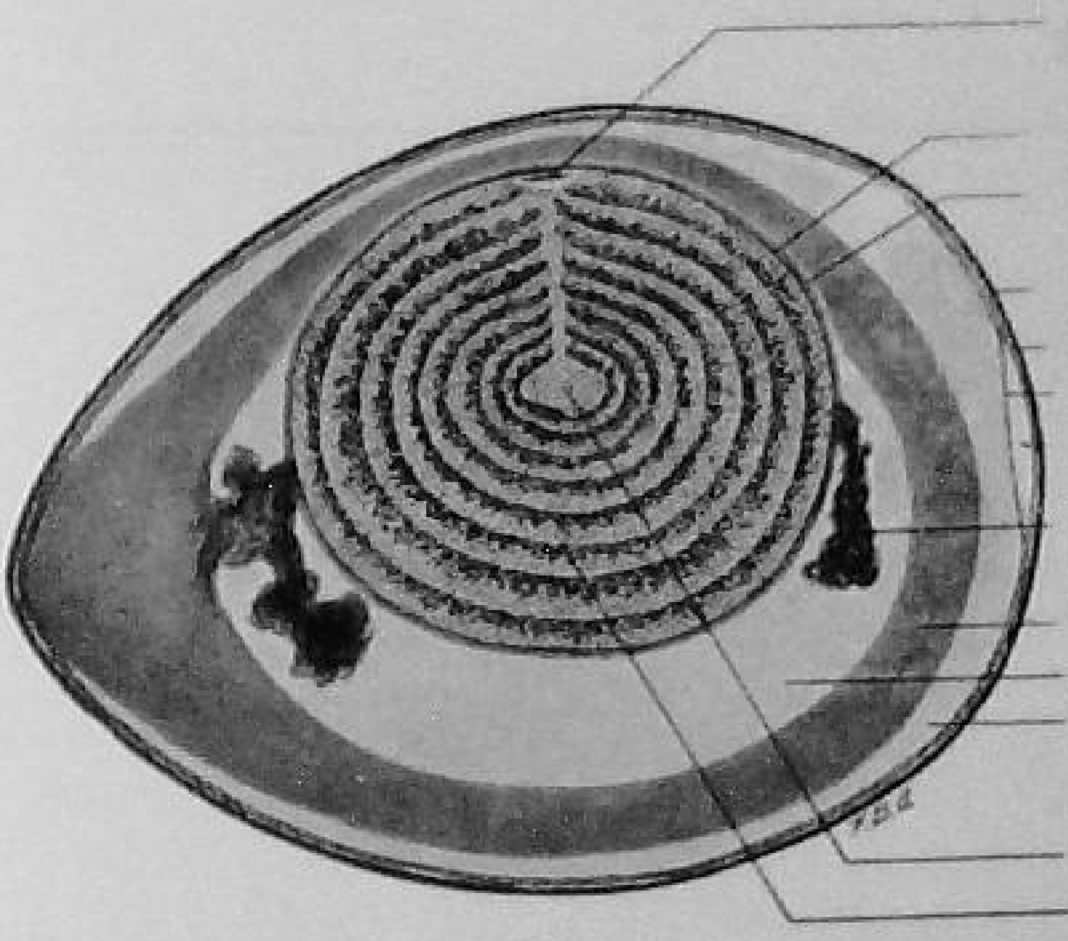


FIG. 31.—Composite diagram showing, in vertical section, the parts of a fresh pullet egg. (*Courtesy of F. B. Adamstone.*)

The Yolk.—From the standpoint of the packing-house breaking room, the yolk of an egg is a globular mass of more or less highly colored, palatable and very nutritious semi-liquid, for which there is a considerable commercial demand, and without which pastries may not reach their full perfection. In a technical sense the yolk of the kitchen and of commerce, with its germinal disc, or blastoderm, *is the egg*, though it is customary to refer to it as such only when surrounded by its complement of white, shell membrane and shell.

It is enclosed in a transparent membrane known as the vitelline membrane, which is responsible for its maintaining a nearly spherical shape. The material making up the body of the ovum, serves as the chick's first and last food during prehatching life, and its first after it escapes the shell.

The White.—Immediately surrounding the yolk, and adhering closely to the vitelline membrane, is a layer of very dense white

called the chalaziferous layer. This is prolonged toward the ends of the egg in two whitish, opalescent, convoluted strands called chalazæ, because of a fancied resemblance to hailstones. These prolongations are twisted in opposite directions. The line describing the long axis of the egg passes through them in an egg that has been rotated recently, so that the position of the yolk is central.

Surrounding the chalaziferous white is a spiral layer of faintly pigmented dense albumen referred to as the thick white, which comprises from 40 to 60 per cent by weight of the total white of the egg. The dense white, as a whole, will not flow readily, but holds together in a flattened mass when poured out upon a plate, if the egg is new-laid. This layer of firm white holds an inner layer of liquid white, as can easily be demonstrated by drawing the point of a knife through the firm white of an opened egg. This suggests

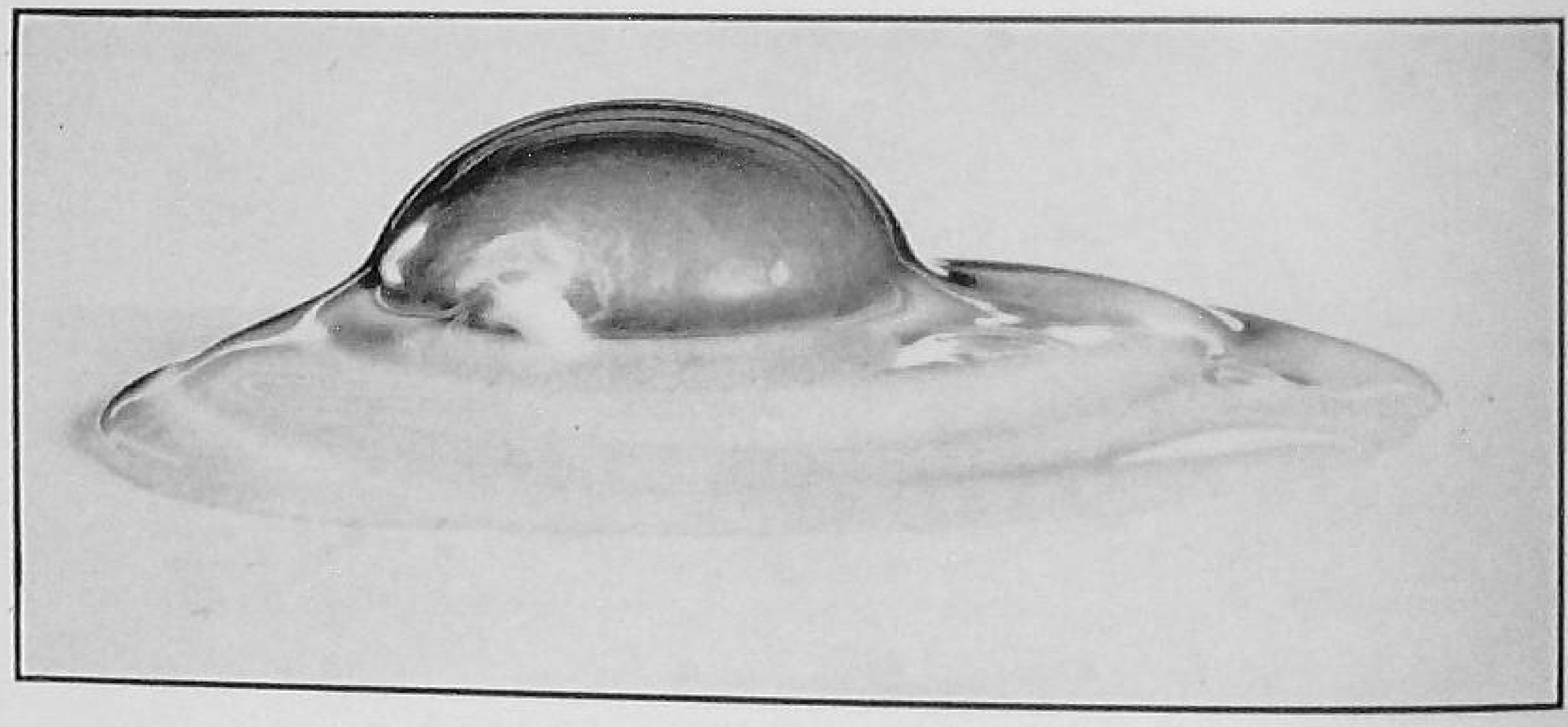


FIG. 32.—Appearance of a new-laid egg of AA quality. Note how both the yolk and the thick white "stand up."

an explanation for some of the "watery white" eggs of commerce, since rough handling may conceivably bring about a rupture of the layer of dense white, thus causing an apparent liquefaction of the egg. The spiral formation of the white may be noted by carefully dissecting an egg boiled to medium hardness.

Surrounding the thick white in turn is more liquid white (also frequently referred to as "thin," "watery" or "fluid"), which is mucilaginous in character. The difference between the dense and liquid white is easily seen when a new-laid egg is broken into a dish.

Although these four layers of white are readily distinguished in a fresh egg, it is of interest to observe how and when they become differentiated. There is normally no evidence of an inner thin layer until after the forming egg has left the isthmus. The same is true of the chalazæ. And of course the uterine secretion which

makes up half the total white by volume is not added until the egg reaches the uterus or shell gland.

Through a combination of enzyme action, some dilution of the thick white by the uterine secretion (which approximates normal saline solution in density), and rotation of the egg in the uterus, there is brought about the differentiation of the egg white into the inner or chalaziferous layer; the chalazæ; the inner thin white, which is completely enclosed in the dense layer; the thick or dense white, which retains the egg shape when broken out into a saucer: and the outer thin white.

The continued break-down of the thick white, with corresponding increase in the amount of thin white is one of the major changes involved in the deterioration of egg quality.

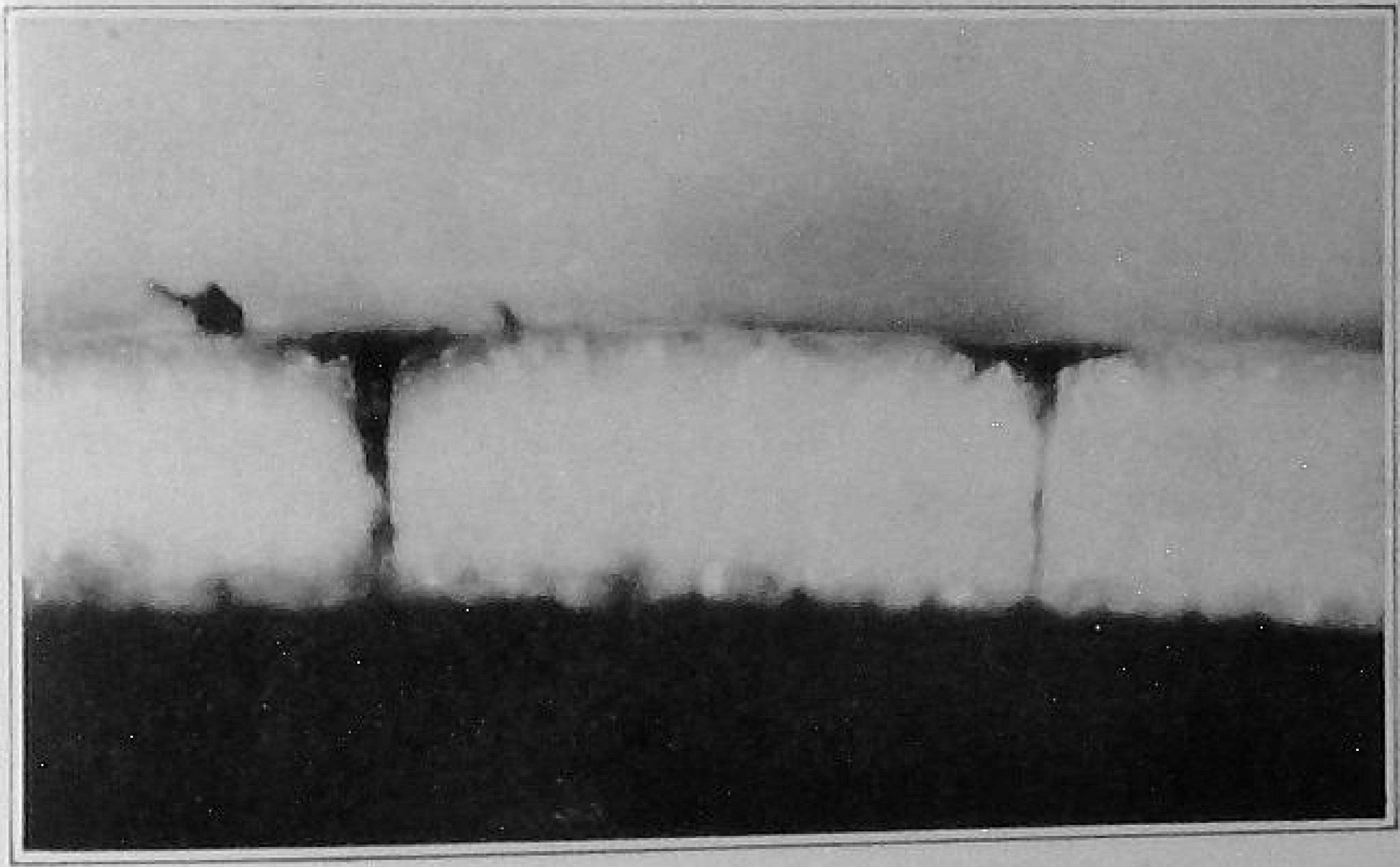


FIG. 33.—The edge of a broken shell, showing two pores partially filled with the external cuticle or bloom (enlarged 60 times). (*Courtesy of California Agricultural Experiment Station.*)

The Shell Membranes.—Surrounding the white of the egg are two white papery membranes referred to as the inner and outer shell membranes. Both are composed of matted organic fibers crossing one another in all directions. The outer membrane is about three times as thick as the inner one, average measurements having been reported as 0.05 and 0.015 mm., respectively.

These membranes normally adhere to each other quite closely, except at the large end of the egg where usually they are separated to form the "air cell." The air cell is quite small when the egg is first laid, but progressively increases in size as the egg cools and as water later escapes from the contents by evaporation through the membranes and the shell.

The position of the air cell is quite variable. though usually so situated at the large end that the line describing the long axis of the egg will pass through it at some point. Occasionally, however,

it is found at the small end, or at various positions between the ends.

The Shell and Its Cuticle.—The inner shell layer consists of knob-like crystals of calcite. If an egg is removed from the oviduct at the proper stage of development, the shell will be found to consist entirely of this crystalline material.

TABLE 15.—APPROXIMATE CHEMICAL COMPOSITION OF THE EGG AND ITS PARTS.

	Entire egg	*Egg contents*	*Yolk*	*White*	*Shell and membranes*
Water	66%	74%	48%	88%	2%
Dry matter	34	26	52	12	98
Protein	12	13	17	11	6
Fat	10	11	33	—	—
Carbohydrates	1	1	1	1	—
Ash	11	1	1	—	92

As shell formation proceeds, there is deposited a chalky layer which comprises about two-thirds of the entire shell. This layer consists of very small calcite crystals of irregular shape, arranged so that their long axes are about perpendicular to the shell surface.

Extending through the egg shell are pores or channels which permit gaseous exchange to take place. In fresh eggs the number of open pores is normally small, but under the influence of high temperature, the number of visible pores is greatly increased. As many as 8000 pores have been observed in a single egg.

When an egg is first laid, it appears moist because it is coated with mucus. This quickly dries, leaving a residue called the cuticle, which partially seals the pores of the shell.

Composition of the Egg.—The physical composition of a 2-ounce egg, by weight, is about 10 per cent shell, 30 per cent yolk, and 60 per cent white. The white consists of outer thin white 23 per cent (range from 10 to 60), dense white 57 per cent (range from 30 to 80), inner thin white 17 per cent (range from 1 to 40), and chalaziferous white 3 per cent.

Large eggs contain proportionately more white and less yolk than small eggs. The percentage of shell remains very nearly constant, except that the first eggs laid by pullets carry relatively more shell and less yolk than is characteristic of eggs in general. The last egg of a clutch, at least for clutch sizes of 2 to 7, usually has a thicker shell than the egg which preceded it, presumably because it has spent a somewhat longer time in the uterus.

The approximate chemical composition of the egg and its parts is shown in Table 15.

CHAPTER 3

PRINCIPLES OF POULTRY BREEDING

Productive poultry breeding has made tremendous progress since the beginning of the present century. Hens with a first-year production of 300 eggs are as common as 200-egg hens were twenty-five years ago. Egg size has been brought under practical genetic control, slow feathering has been eliminated from many flocks, and many other characters have been improved by selection. It is quite evident, however, as was indeed inevitable, that the rate of progress is slowing down, especially with respect to the egg production of superior flocks.

Further improvement will depend on a refinement of selection methods and practices. As we learn more about poultry breeding, it becomes more complex and more difficult. There is no simple, easy, rule-of-thumb method by which a flock average of 300 eggs a year may be attained. Once the basic principles are understood, the most fruitful plan is to apply those principles in a flexible system which permits the breeder to take full advantage both of new information and of families or individuals of exceptional merit whenever they are found. But continued progress will require all the skill of which poultrymen are capable.

HEREDITARY BASIS OF IMPROVEMENT

It is probably correct to say that all characters in the fowl are influenced by both heredity and environment. With some characters the influence of environment is very slight, so slight that there is never any question as to the proper classification of an individual with respect to the character in question. Certain other characters may be so greatly influenced by environment that it is difficult to demonstrate any hereditary influence at all. Those of the first sort—comb type, for example—are said to have a high degree of heritability, because the amount of individual variation which is traceable to environment is extremely small, even non-existent in the case of single comb in the sense that there is never any difficulty about classifying a particular comb as single. Comb size, as influenced by environment, is another matter. Characters at the other extreme are said to have a low degree of heritability because the amount of individual variation traceable to heredity is small, while that traceable to environment is very large.

For single comb, then, it is sufficient to know that it is one form of a character which is highly heritable, that it is recessive to the type of comb called rose, and that selection for the single type is immediately and completely effective. In other words, if a male and a female possessing single comb are mated together, they will breed true for that character. All of their offspring will have single combs, and they in turn will likewise breed true for that particular character. Of course poultry breeders are also concerned with such things as the number of points on a single comb, the shape of the blade, the overall size, and the texture of the surface. Our example refers only to comb type or shape.

Single comb is said to be recessive to rose comb because, if an individual with a single comb is mated to one which is pure for rose comb, the single comb character will not appear in the next generation. All of the offspring will have rose combs, but if any two of these are mated together, the single comb character will reappear in about one-fourth of *their* offspring. This is an example of the familiar 3:1 Mendelian ratio between simple dominant and recessive characters. Of those individuals which show the dominant character, about one-third will be true-breeding rose, while two-thirds (one-half of the entire generation) will be like their parents. The true-breeding individuals, either rose or single, are said to be *homozygous*, while the remaining rose-comb individuals are described as *heterozygous*.

Many simple characters in poultry are inherited in the same manner as rose and single comb, while certain others are much more complex. We shall consider a number of characters for purposes of illustration, proceeding from the simple to the complex and, in a very rough way, from high heritability to low.

Market poultry with yellow skin is prized in some areas, while in others the preference is for white skin. Genetically, white and yellow skin color constitute a pair of characters just as do rose and single comb, white skin being almost completely dominant to yellow. As every poultryman knows, yellow skin is subject to bleaching until it is practically indistinguishable from skin that is genetically white. Feeding fowls on a ration which is entirely devoid of the pigment xanthophyll will cause the yellow color to disappear after a time. Females which lay continuously will lose all of their yellow color, even though their ration may be high in xanthophyll for the entire time. On the other hand, white-skinned fowls will not develop yellow color even when fed rations high in such xanthophyll-containing feeds as yellow corn and green forage. Here, then, is an example of a character which in a technical sense exhibits high heritability, but only if observed at the right time and under specified conditions.

Plumage colors in poultry are, in general, characterized by a high degree of heritability. Environmental influences such as inadequate

rations may cause some variation, but seldom enough to interfere with accurate classification of individuals with respect to plumage color. An interesting example, which serves also to illustrate incomplete dominance, is the Blue Andalusian. These fowls never breed true for color. The offspring of blue parents occur in the ratio of 1 black to 2 blue to 1 blue-splashed white. The blacks behave genetically like any other blacks, while the blue-splashed whites are homozygous, and the blues heterozygous, for a gene which dilutes black plumage color. The heterozygous individuals are distinguishable by appearance, and the phenotype ratio is therefore 1:2:1 instead of 3:1. It so happens that the blue heterozygote is the desired type. Breeders may therefore maintain stocks of black and blue-splashed white fowls in order to obtain 100 per cent blue offspring when these two kinds are crossed.

The common 3:1 ratio may be modified in other ways as, for example, by any one of several lethal or semi-lethal genes which interfere with or prevent normal hatching. The short-legged mutation known as creeper is caused by a gene which in homozygous condition completely prevents hatching and in heterozygous condition reduces it slightly. Here again the observed creeper condition in mature fowls is the heterozygous form. When creepers are mated together, the resulting offspring consist of creepers and normals in the ratio of approximately 2:1. Some of the heterozygous creepers die just before hatching, while all of the homozygotes die earlier, and the common 3:1 ratio is therefore changed not to 1:2:1 but to 0:2:1. The creeper condition is regarded by most poultrymen as undesirable. It can be eliminated by the simple procedure of discarding creepers and breeding only from normal fowls. Recessive lethal genes, on the other hand, pose more of a problem because individuals carrying such genes in heterozygous condition cannot be distinguished from normals by appearance. They can be detected only by suitable breeding tests to be explained later.

SEX DETERMINATION AND SEX LINKAGE

To return to plumage color for another example, all fowls so far as is known, carry either the gene for silver or the gene for gold. The gene for silver gives the plumage a silver (white) background on which various black patterns are superimposed, while the gene for gold causes a gold (red, brown or buff) background for such patterns. The presence of either gene may be masked by solid black or by the presence of genes which inhibit color. In the inheritance of characters of the sort previously chosen as examples, it makes no difference in the progeny whether it is through the sire or the dam that the dominant gene of a given pair is introduced. But in the case of genes for silver and gold, and indeed for several other gene pairs in the fowl, it makes considerable difference. This is because

the genes for silver and gold are carried on the sex chromosomes, of which the male fowl always has two and the female only one.

Every fertilized egg receives a sex chromosome from the male parent, but whether or not the egg contains a sex chromosome from the female which laid the egg is purely a matter of chance. Approximately half of them do, while the other half do not. If the egg carries a sex chromosome it will, when fertilized, give rise to a male

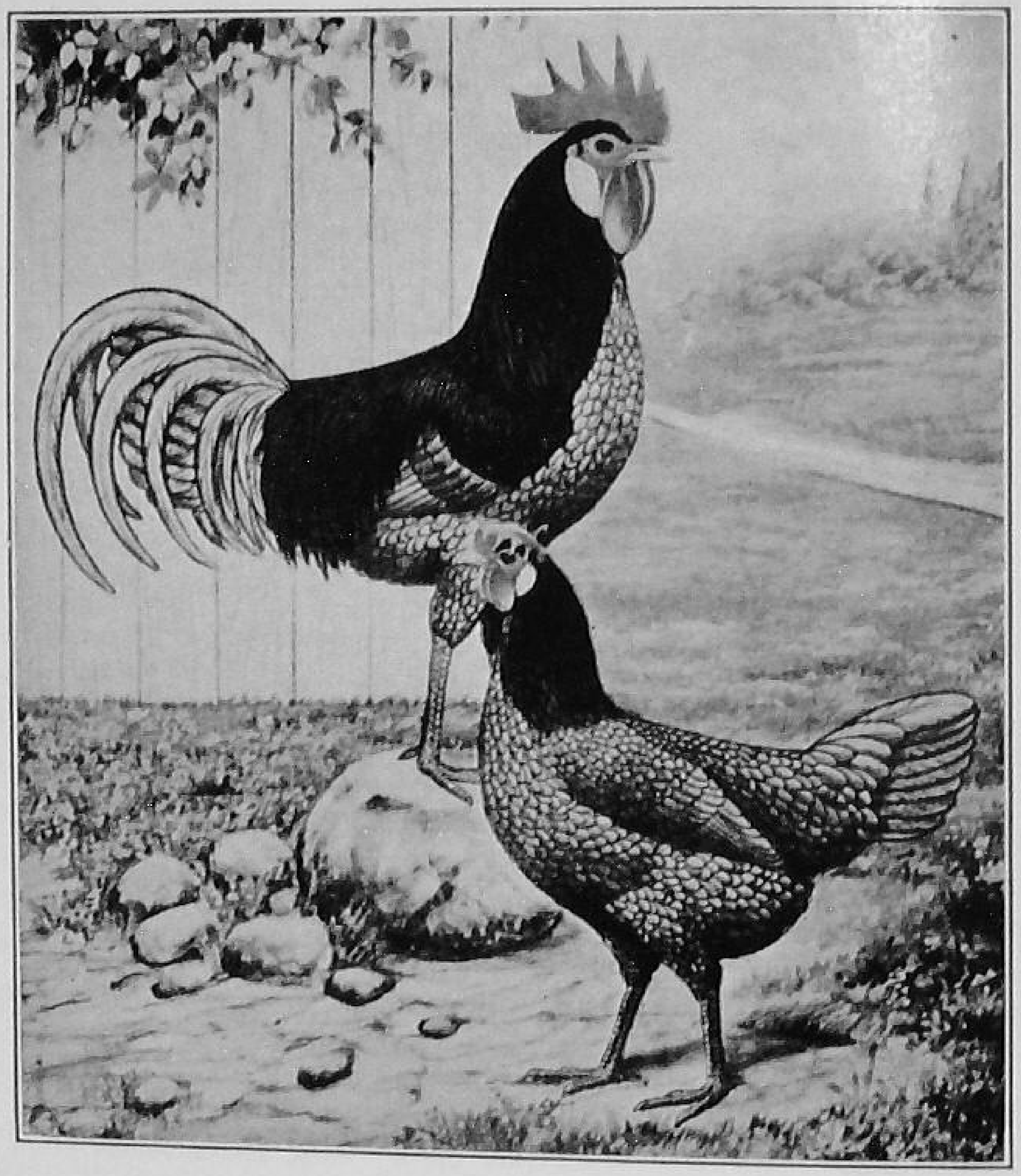


FIG. 34.—The Blue Andalusian is a heterozygous form which never breeds true for color. (*Courtesy of Poultry Tribune.*)

chick. If the egg does not contain a sex chromosome it will, after fertilization contain only one, and will therefore produce a female chick. By this simple device the sexes are maintained in approximately equal numbers.

Because females produce eggs both with and without a sex chromosome and thereby determine, albeit entirely by chance, which are to become males and which are to develop into females, the females are said to be *heterogametic*. Other chromosomes, often called *autosomes*, invariably occur in pairs so that an individual not only has

the same number of chromosomes in all its body cells as every other individual of the same species, but has a pair of genes for every character in question, one from its sire and one from its dam. If the genes are alike, the individual is *homozygous* for that gene and will breed true in respect to it. If the genes are unlike, the individual may transmit either to any individual offspring and is therefore

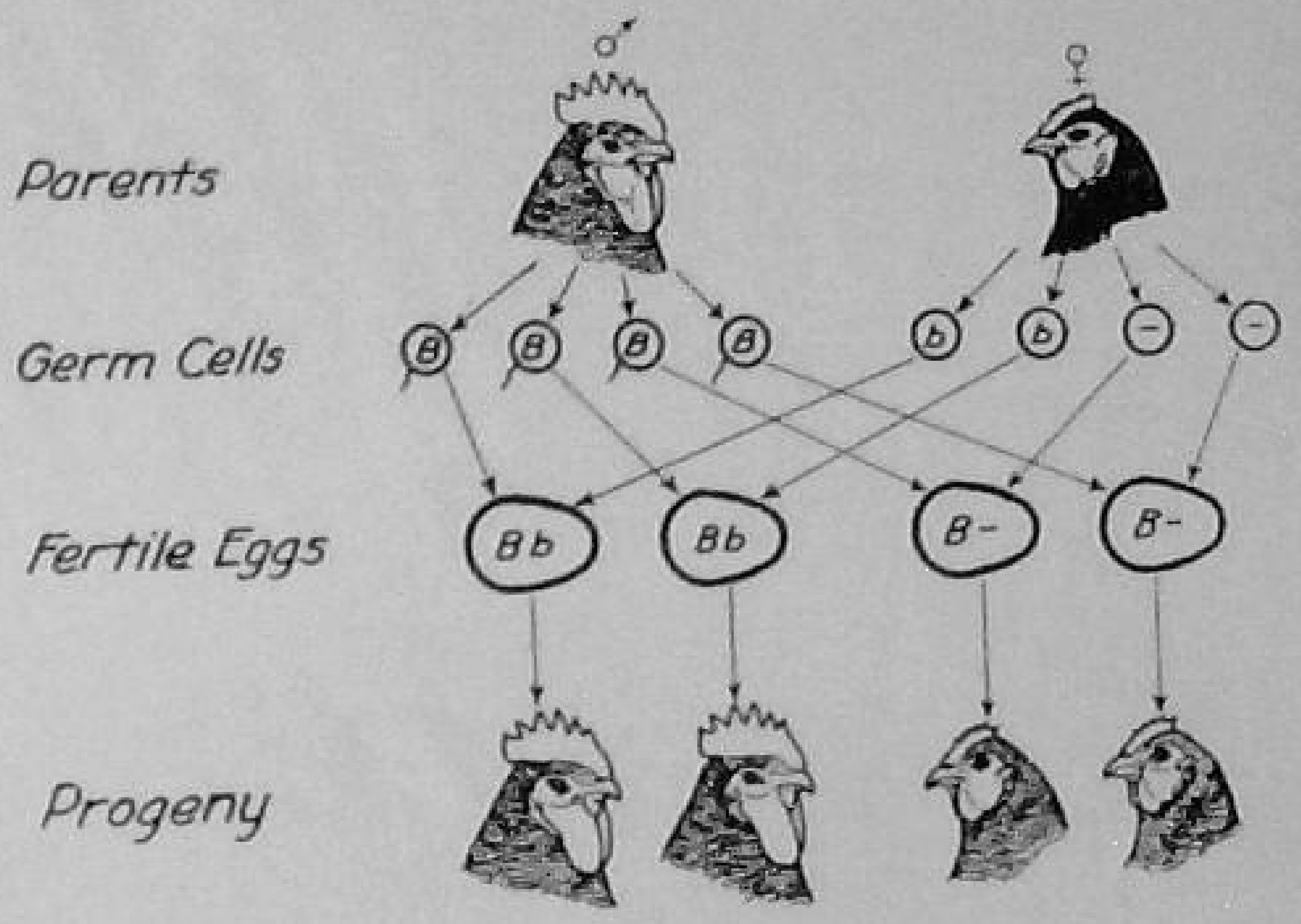


FIG. 35.—Showing the transmission of a dominant sex-linked character, barring (dominant to non-barring) when introduced by a male pure for the character. Compare with Figure 36.

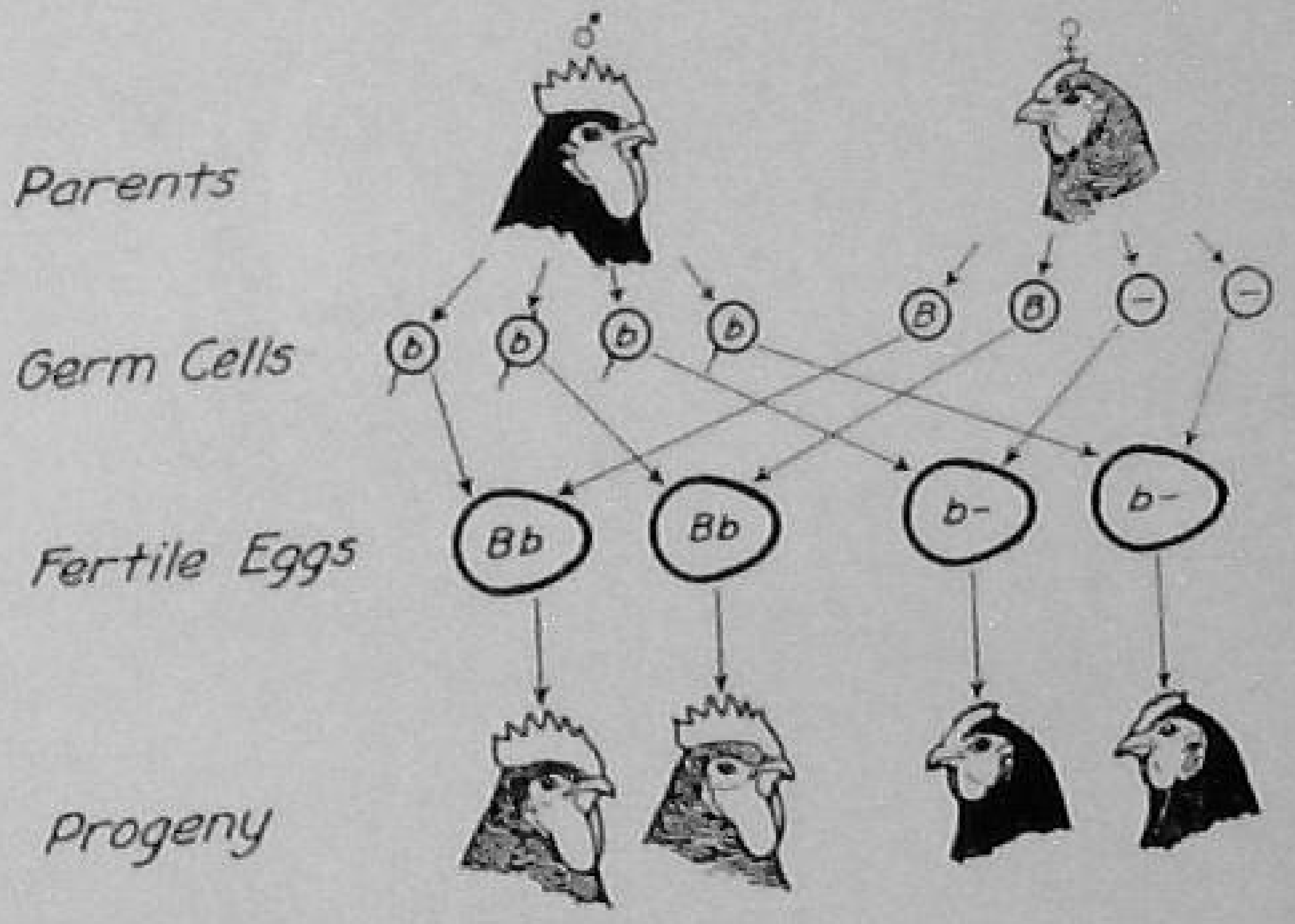


FIG. 36.—Showing the transmission of a dominant sex-linked character, barring (dominant to non-barring) when introduced by a female showing the character. Compare with Figure 35.

heterozygous with respect to the character. It is only in the case of the sex chromosomes, and then only in the female, that an individual may receive but a single gene for a particular character. Genes of this sort, that is, all genes which are carried on the sex chromosomes, are called *sex-linked* genes, and the characters which they determine are called sex-linked characters. Barring as found in Barred Plymouth Rocks is another example.

Making Use of Sex Linkage.—The manner in which sex-linked characters are transmitted makes it possible to use some of these characters for rapid and accurate sex identification of day-old chicks. The only requirement is that the character be one that can be seen

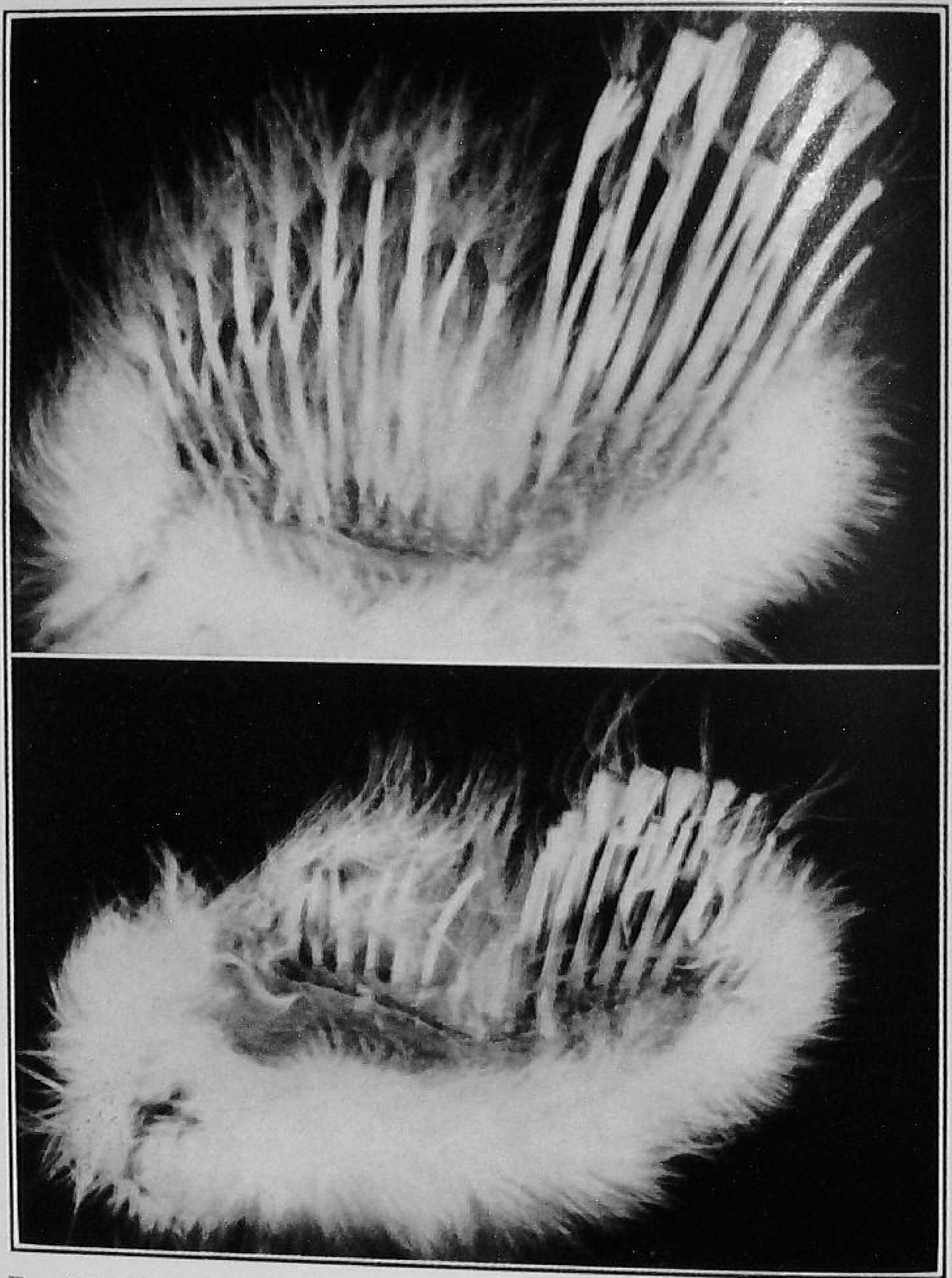


FIG. 37.—Slow feathering is dominant to rapid feathering and sex-linked. The difference is apparent in newly hatched chicks. In the rapid-feathering chick (*above*) the primaries and secondaries are longer than the coverts. In the slow-feathering chick (*below*) the primaries and coverts are about equal in length.

at hatching time. Any silver female, when mated with a gold male, produces chicks in which the males are genetically silver and the females gold. Unless they are obscured by some form of dark down color, it is therefore a simple matter to separate the silver (male) chicks

from the gold females. If the cross is made the other way around, silver male and gold female, all of the chicks will be silver and the recessive gold will not appear, provided the male parent is homozygous for the gene for silver.

Exactly the same procedure can be followed with respect to the genes for barring and non-barring. If barred females are bred to non-barred colored (usually black or red) males, the resulting male chicks will be barred, as evidenced by a characteristic white head

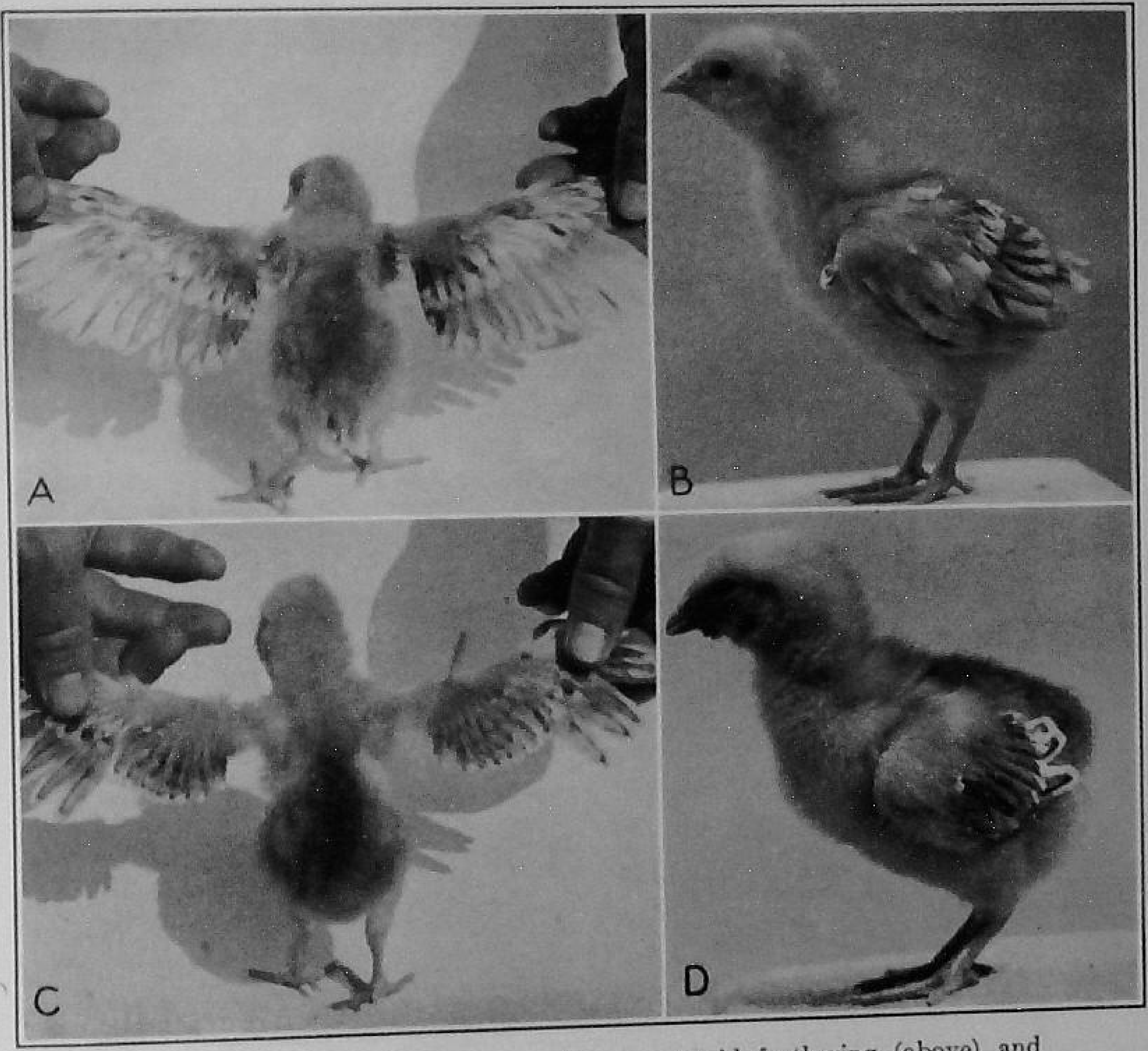


FIG. 38.—Showing the difference between rapid feathering (above) and slow feathering (below) at ten days of age.

spot appearing on the black down, while the females will be solid black in head color. If a pure-bred (homozygous) barred male is used with non-barred females, all of the chicks will be barred.

Another sex-linked gene affects rate of feathering in chicks, and it can be used in the same manner. Leghorns and some other breeds are characteristically rapid feathering, whereas most of the American and other heavy breeds are slow feathering. Slow feathering is dominant to rapid, and if the cross is to be used for sex-identification it is

therefore necessary to mate rapid-feathering males with slow-feathering females. At hatching time the rapid-feathering female chicks from such a cross show well-developed primaries and secondaries which not only extend well beyond the down, but which are also longer than

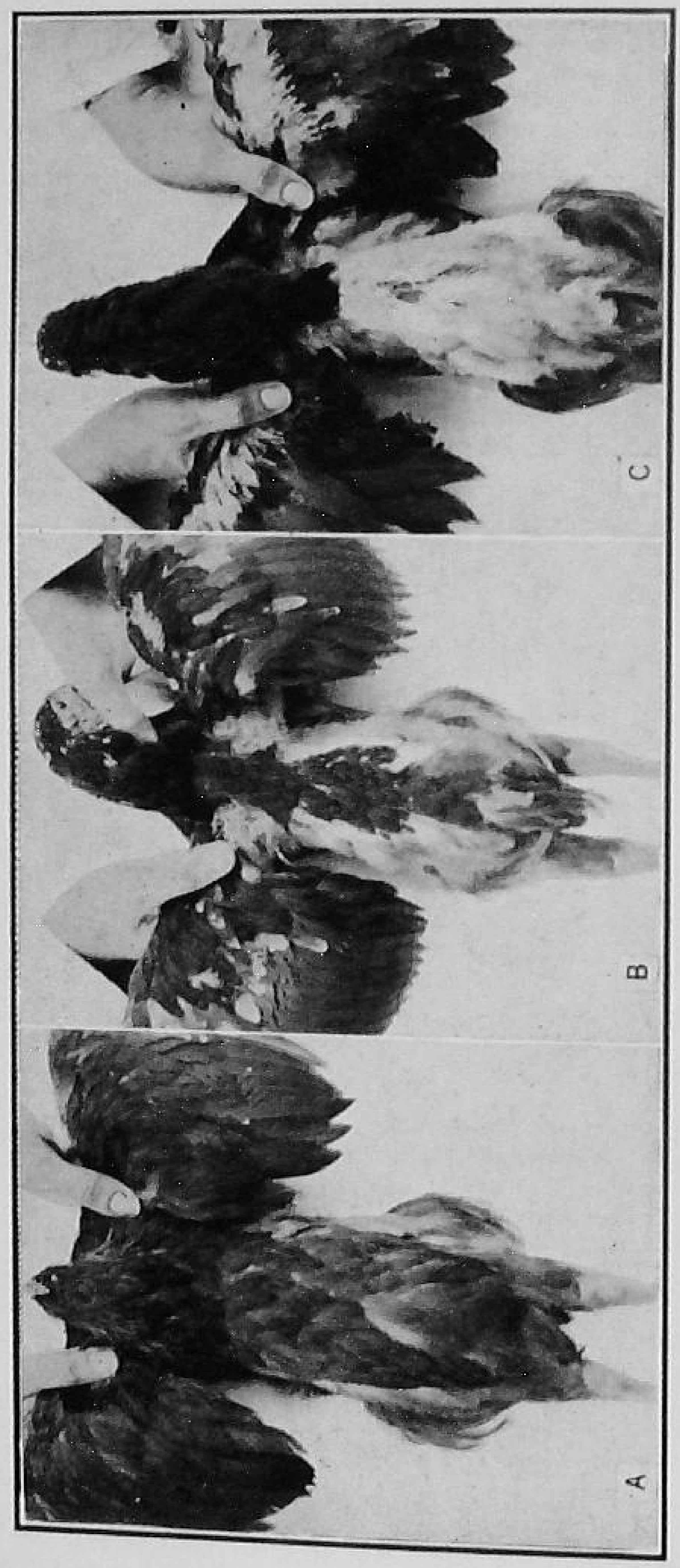


FIG. 39.—In breeds or strains which lack the sex-linked recessive gene for rapid feathering, there is often great variation in rate of back feathering caused by autosomal genes. (*Courtesy of Massachusetts Agricultural Experiment Station.*)

the associated wing coverts. In the slow-feathering male chicks, by contrast, the primaries are much shorter, are of about the same length as the coverts, and the secondaries are either absent or very poorly developed. Later on, at about ten days of age, the rapid-feathering chicks show well-developed tail feathers, wing feathers extending to

the tail, and a small tuft of feathers on each shoulder. The slow-feathering chicks show no tails and much shorter wings. These differences are shown in the accompanying pictures. (Figs. 37, 38.)

It must be remembered that feathering is influenced by other genes as well, and that even more serious to broiler growers in particular is the type of slow feathering which is autosomal rather than sex-linked. It has been shown that family selection for good back feathering at eight weeks of age is rather quickly effective. The characteristic differences in back feathering are shown in Figure 39. Various other modifying genes affect both rate and condition of feathering, but they are less important than the ones which have just been discussed.

QUANTITATIVE CHARACTERS

All of the characters thus far considered belong in what may be described as an "either or" category. There is no gradation by almost imperceptible degrees from rose comb on the one hand through some intermediate form to single comb at the other extreme. But with most of the economically important characters, variation is of the continuous type found in all quantitative characters. Egg size, for example, varies all the way from something under 45 grams to as much as 75 grams. It would not be difficult to find eggs among those produced by almost any large flock which would represent every weight, by one-gram intervals, from 45 to 75 grams. If enough eggs were weighed, it would undoubtedly be possible to find also individual eggs weighing 45.1, 45.2, 45.3 grams each, and so on by one-tenth-gram intervals up to 74.7, 74.8 and 74.9 grams. How then is one to describe and classifly eggs according to weight for the purpose of determining how egg weight is inherited? Classifications must obviously be made in some arbitrary manner. And after the upper and lower limits have been chosen for small, medium and large eggs, how is one to determine what genes are involved, and how many pairs of such genes there are? Clearly, this is not so simple a problem as the inheritance of rose and single comb.

For our purpose it is not so important to determine exactly how many pairs of genes are involved, as to recognize that variation in egg size is the result of the influence of more than one pair of genes, that the exact number cannot easily be determined, and that selection for egg size is therefore a somewhat different problem from selection for comb type or plumage color.

A great many things have been learned about egg size, and some of this knowledge can be useful to poultry breeders. We know that egg size is correlated with body size, especially among the smaller breeds of chickens. Selection for large egg size within a breed or variety tends to increase body size at the same time, though not all large fowls lay large eggs. Even seasonal changes in body weight

and egg weight tend to be associated so that a spring and fall maximum for each is fairly well defined, at least during the first laying year.

Since the quantity of feed nutrients which must be digested, metabolized and deposited in 300 small eggs is less than for the same number of large eggs, it is easier to develop families and strains of high-producing fowls if no attention is paid to egg size. Conversely, selection for large egg size places a handicap on the rate of improvement which can be made in egg production, but market demands make it almost mandatory on poultry breeders to strive for egg production performance which not only includes a reasonable minimum average egg weight of between 24 and 25 ounces to the dozen, but which involves a minimum number of small eggs from each pullet.

It has been repeatedly demonstrated that selection for increased egg size is rather quickly effective, so that the present market standard of a 2-ounce minimum for individual eggs can be attained within a period of two to four years of family selection. This is perhaps comparable to the problem of increasing average flock egg production to about 160 eggs a year. Whether it would be any easier to increase average egg weight to $2\frac{1}{2}$ ounces than to increase average egg production to 240 has apparently never been determined. For practical purposes, however, we can say that egg size, within the limits of present market desirability, has a fairly high degree of heritability.

Body size is another quantitative character in which many poultrymen have a direct interest. For our purpose it is important to distinguish between adult weight, and various intermediate weights which may vary widely because of differences in rate of growth to the age at which weight is measured. By no stretch of the imagination could we expect a chick hatched from an egg laid by a bantam hen and fertilized by a bantam male to grow to the size of an adult Plymouth Rock, but the percentage rate of growth of bantams and Plymouth Rocks for a short time after hatching might not be so very different. Rate of growth as reflected by average weight at, let us say twelve weeks of age, is greatly influenced by environment, including the kind and amount of feed consumed. Final adult weight on the other hand, is largely determined by genetic influences, though the time required to reach the maximum may show wide variation, depending on the effects of environment.

Crosses between large and small breeds of chickens, such as Leghorn and Brahma or Hamburg and Cornish, always produce offspring which at maturity are intermediate in size, usually averaging somewhat above the midpoint between the parental stocks. On the other hand, crosses between breeds which are of about the same size often produce offspring which outstrip their parents in rate of

growth to ten or twelve weeks of age. This characteristic is important to producers of commercial broilers.

There can be no doubt that both adult weight and rate of early growth are highly variable within breeds as well as between breeds, or that they are influenced directly and indirectly by a great many different genes. And yet each is readily influenced by selection. Even mass selection with no reference to family performance will bring about a significant change. This can only mean that both of these quantitative characters have rather high heritability.

EGG PRODUCTION

To the vast majority of poultrymen no other character is quite so important as annual egg production. It is now often calculated by a method which includes the effect of adult mortality. Dividing the total number of eggs laid during the year by the number of pullets or hens housed at the beginning of the year gives a value known as the hen-housed average or the production index. A high death loss during the year will lower the index, even though the surviving hens may have laid exceedingly well.

No other character with which we are concerned is subiect to such wide variation within a practical range as is egg production. Hens may lay all the way from 150 eggs to 350 eggs a year and still make money for their owners. No other character involves a combination of genetic and environmental influences which present an improvement problem so intriguing, so challenging, and at the same time so difficult of solution as does the complex character egg production. As indicated at the beginning of this chapter, tremendous progress has been made in improving egg laying performance, and yet no one has the faintest idea how many pairs of genes are involved. Neither do we know how to set up a selection and breeding program that can be guaranteed to push egg production to any predetermined high level. It will be worth while to examine the entire question in some detail. For this purpose we shall use the egg production of survivors rather than the production index.

Analysis of Laying Performance.—There are authentic individual records of 350 or more eggs in twelve months, and there are also records of hens laying no eggs at all in the same length of time. Whether the performance of any given hen falls in the upper or lower part of this range will depend upon the rate at which she lays, and on how much of the time she is in laying condition. For the purpose of analyzing the performance record, it makes no difference whether the stimulus to laying is of genetic or environmental origin. Normally, of course, both sorts of stimuli are at work.

Intensity or Rate of Laying.—Some hens lay only on alternate days, some lay two days out of three, some lay three days before

skipping a day, and a few lay every day for one hundred or more consecutive days.

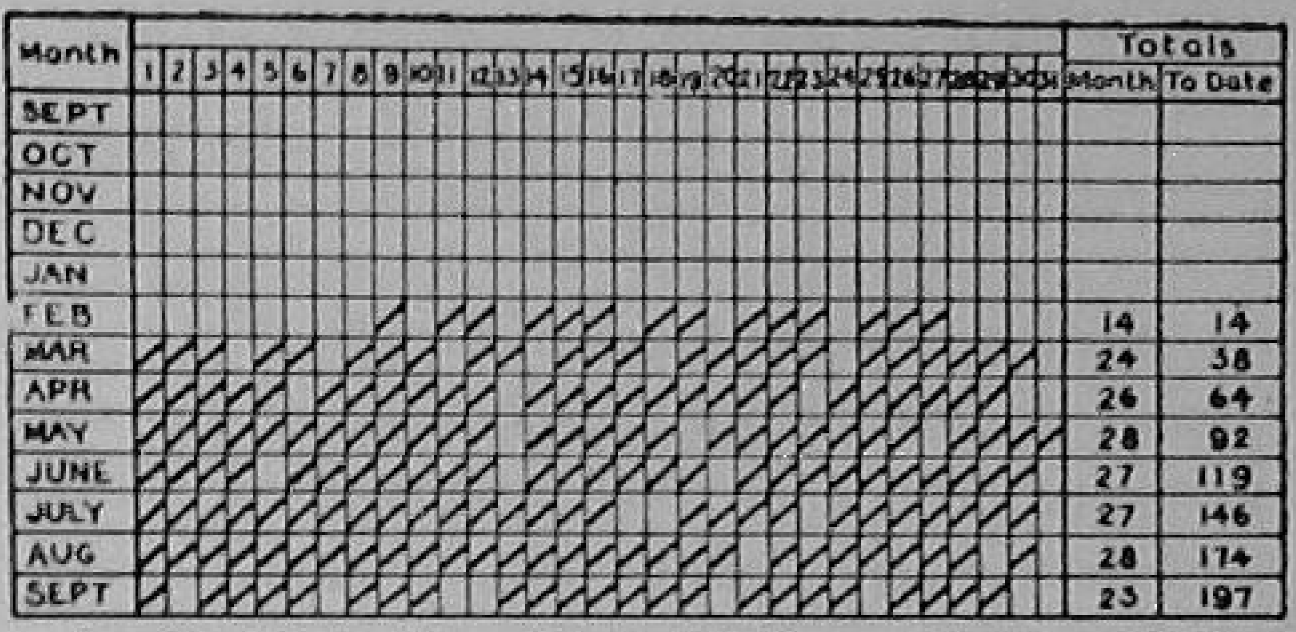
The eggs laid by a hen on consecutive days are referred to as a *clutch*, and clutch size is therefore one of the hereditary characteristics which helps to determine the annual egg record. It is of course influenced to some extent by environment, as well as by natural variation, so that no hen can be expected to lay exactly 4 eggs in every clutch throughout the year. Nevertheless, differences in average clutch size are definitely correlated with annual egg yield.

CLUTCH SIZE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	TOTAL
1	x		x		x		x		x		x		x		x		x		x		x		x		x		x		x		15
2	x	x		x	x		x	x		x	x		x	x		x	x		x	x		x	x		x	x		x	x		20
3	x	x	x		x	x	x		x	x	x		x	x	x		x	x	x		x	x	x		x	x	x		x	x	23
4	x	x	x	x		x	x	x	x		x	x	x	x		x	x	x	x		x	x	x	x		x	x	x	x		24
5	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x		x	x	x	x	x		x	x	x	x	x		25
6	x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x	x		x	x	26
7	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	27
8	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x	x	27
9	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		27
10	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	28

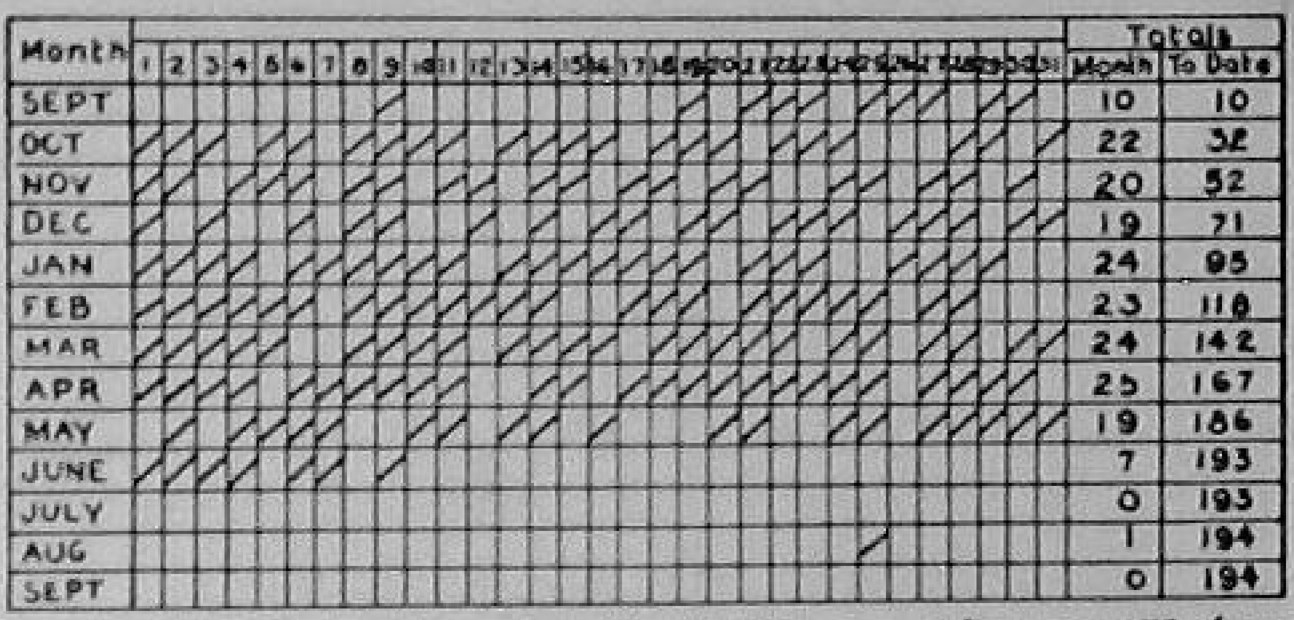
FIG. 40.—Effect of clutch size (number of eggs laid without a skip) on the total number of eggs laid in a 30-day period. An average clutch size of three or more is essential to making a high annual egg record.

If a hen lays in clutches of single eggs, the most that she can lay in a thirty-day month is 15 eggs. If she lays 2-egg clutches, her maximum record in thirty days is 20 eggs, an increase of $33\frac{1}{3}$ per cent. Should she lay in 3-egg clutches throughout the month she could make a total of 23 eggs, which is a further increase of 15 per cent over the 2-egg clutch maximum. Further increases in clutch size to 4 eggs and 5 eggs, respectively, add only one more egg each time to the maximum thirty-day total. The practical problem is, therefore, to increase average clutch size in a flock to a minimum of 3 eggs.

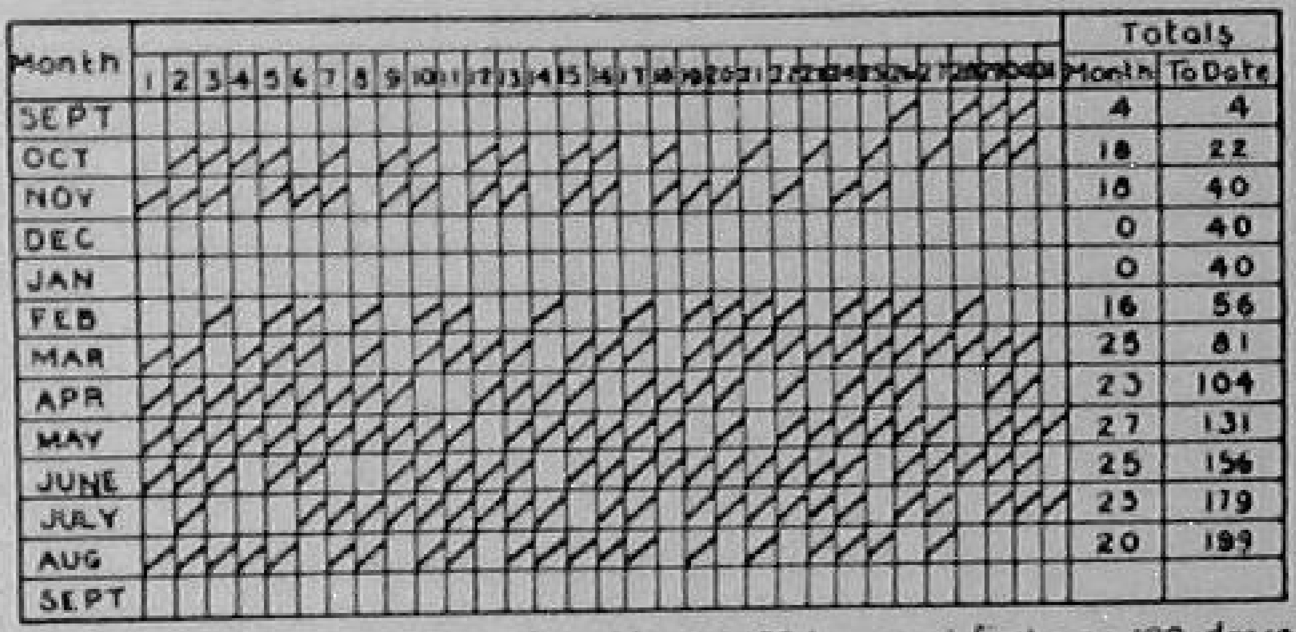
Intensity may also be measured by the number of eggs in a ten-day, thirty-day, sixty-day, or one hundred-day period. Thus one standard of selection might be a minimum of 25 eggs in each of two consecutive winter months. Many variations are possible, depending on the preference of the individual breeder and the particular form in which his records are kept.



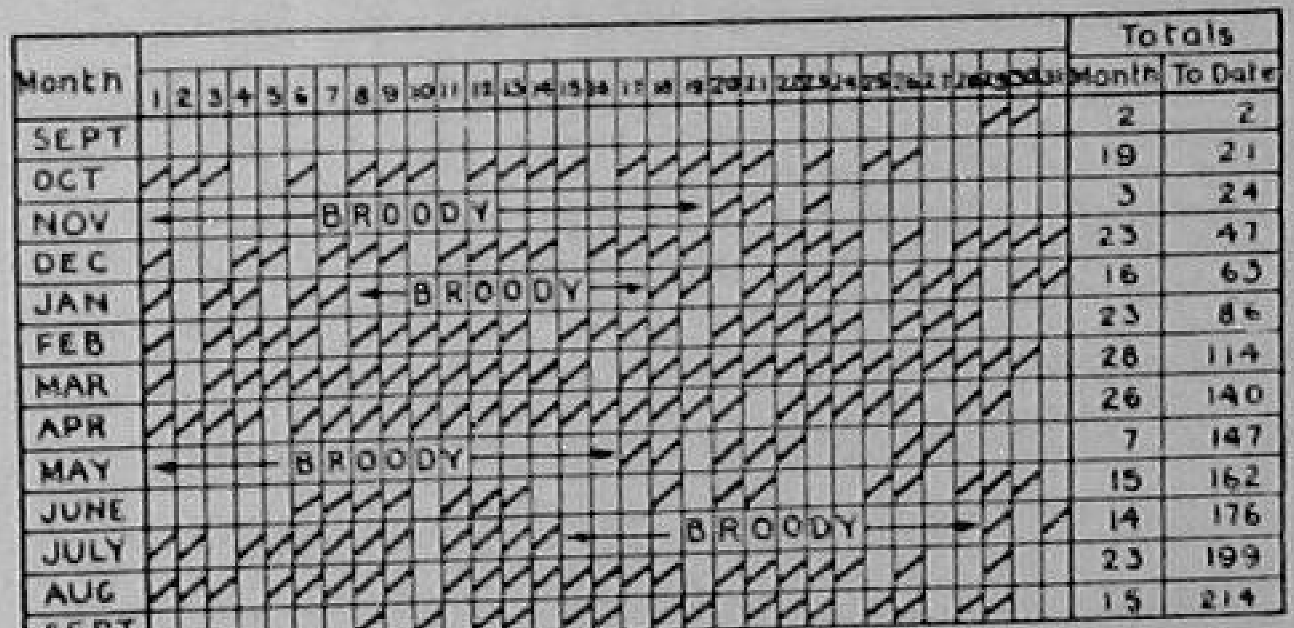
A, Leg band No 896; hatching date Apr 10, 1934; age at first egg, 305 days



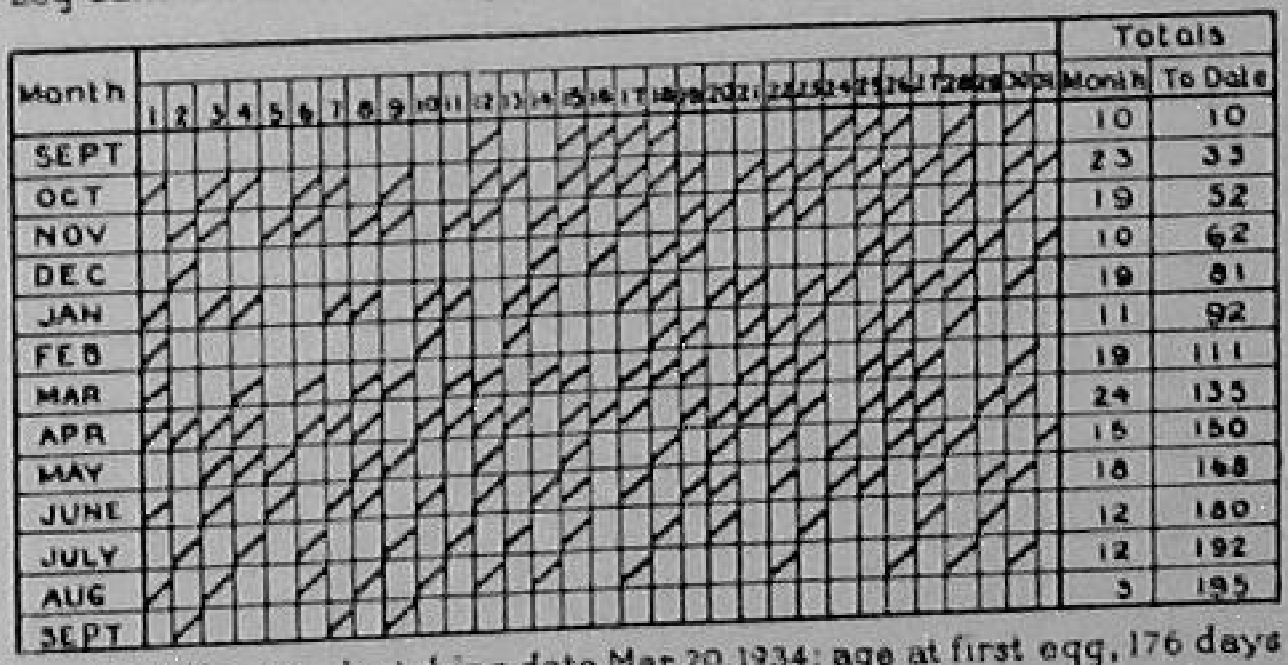
B, Leg band No. J18; hatching date Mar 20, 1934; age at first egg, 173 days



C, Leg band No. J1, hatching date Mar 20, 1934; age at first egg, 190 days



D, Leg band No. J318; hatching date Mar. 20, 1934; age at first egg, 193 days



E, Leg band No. J10; hatching date Mar. 20, 1934; age at first egg, 176 days

Fig. 41.—Each of these hens laid approximately 200 eggs, yet each shows a different fault which prevented the record from being higher. *A*, Late maturity; *B*, poor persistency; *C*, winter pause; *D*, broodiness; *E*, low rate. (*Courtesy of California Agricultural Experiment Station.*)

For an exact analysis it is better to use a third measure, which is called *net rate*. It is calculated by first eliminating pauses of seven days or more within the period under consideration, say December and January, and calculating the percentage of the remaining days on which the hen lays. This is logical because it has been well established that pauses are inherited separately from rate. The net rate of two birds may be exactly the same, whereas their gross rate—calculated without taking pauses into account—can be very different.

FIG. 42.—The record of a "300-egg" hen. Compare with Figure 41. (*Courtesy of California Agricultural Experiment Station.*)

Age at First Egg.—Length of the laying year for pullets is greatly influenced by the time laying commences. This may be measured either in terms of age in days when the first egg is laid or, if date of hatch is not too variable, by the calendar date on which the first egg is laid.

Since there is no necessary relation between age at beginning to lay and the time of beginning the fall molt, which normally marks the end of the laying year, it is obvious that the pullet which begins to lay at an early age is likely to have a longer laying year than one which matures slowly and begins to lay at a later age. In many flocks this difference between the earliest and latest maturing pullets is more than one hundred days, and it may be more than one hundred and fifty days. Extreme cases might show a spread of two hundred days between individual pullets.

Early maturity is hereditary, and is one of the easiest characters to establish in a flock, especially if attention is given to the selection and use of males from early-maturing dams.

There is some danger of over-doing the matter of selection for this character, and getting pullets which mature early at the expense of body size. Such pullets will often lay small eggs. Concurrent selection for egg size is therefore a point of practical importance.

The most desirable age at maturity will vary among breeds and also among strains, but two hundred and fifteen days for the heavier breeds and one hundred and eighty days for Leghorns may be taken as the approximate dividing point between early and late maturing individuals. Environmental factors such as date of hatch, and other management practices, may have considerable influence on the age at which laying commences.

Persistency.—Length of laying year is influenced not only at the beginning by the date of the first egg laid, but also at the end by the date of the last egg. The tendency to continue laying well into the fall or winter is known as persistency, and it has much the same effect at the end of the year as early maturity does at the beginning.

Lack of persistency is easily determined, as a rule, by the beginning of an early molt, because the fall molt normally marks the end of the laying year. Some hens molt as early as June and others as late as December, so that it is easily possible to have a difference of one hundred and eighty days in length of laying year on account of this one factor.

The common practice of culling laying flocks in late summer or early fall is based on the fact that persistency is highly correlated with total annual egg production. Culling out the early molters automatically removes many of the low producers from the flock.

Continued selection for persistency tends to strengthen the "urge to lay" to such an extent that flocks so selected are less likely to be thrown out of production by minor errors in management. In fact persistency may become so well established that it is necessary to use rather drastic measures in order to cause certain flocks to molt in time to be ready for the production of hatching eggs in January or February.

Pauses in Laying.—A pause in laying, as here used, refers to a cessation of laying of one week or more. From the standpoint of selecting for an improved laying performance, there are at least three types of pauses with which the poultry breeder has to deal. These are: (1) environmental; (2) broody; and (3) winter pauses.

The environmental pauses are those brought about by mismanagement, accidents, unusually severe weather, and the like. From the standpoint of the present discussion they are of interest only because it is sometimes puzzling to determine whether a given

bird stops laying because of a hereditary bias, or because she has been mishandled. It is not always possible to tell.

At the same time it must be observed that even a susceptibility to environmental changes probably has a genetic basis, for daughters of some individuals are thrown out of lay easily, while daughters of others will stand a good deal of abuse before stopping.

Broodiness, like many other physiological functions in the hen, is under endocrine control. Increased secretion of prolactin by the pituitary gland causes the hen to go broody. It is of importance in selection and breeding for egg production because a hen normally stops laying when she goes broody. The days lost on account of broodiness may have a marked effect on the annual egg record, especially if the hen goes broody several times and is slow about coming back into production.

In spite of the difficulties, progress can be made in the direction of reducing broodiness in a flock if all broody females and all male relatives of such females are discarded. Any outside stock brought in for breeding purposes, even if from a flock with a history of non-broodiness, should be tested by mating to a few individuals in order to avoid introducing broodiness on a large scale.

Sex-linked genes for broodiness have been found in certain breeds, and must be taken into account in a careful breeding program.

Some hens show pauses in laying without ever going broody. Such pauses are most common during the winter months, but may occur at other times of the year.

Relative Importance of the Various Factors.—An attempt to evaluate the relative importance of the several characters with respect to their effect on first-year egg production has been made by Hays of the Massachusetts Station. He used the records of 1220 Rhode Island Red pullets during the five-year period from 1938 to 1943, during which hatching dates were kept constant and egg size was well above 24 ounces to the dozen.

The five factors studied, and minimum standards for each, were as follows:

1. Early maturity—215 days or less.
2. High winter intensity—clutch size 3 or more.
3. Non-winter pause—shorter than eight days.
4. Non-broody—no broody periods.
5. Persistency—laying year at least 280 days.

The flock was essentially early maturing and non-broody, so that these two factors had different values than they probably would have in an unselected flock. Using the average production of pullets showing all five characters as a standard, a lack of persistency reduced the annual egg record by 55 eggs, a lack of high intensity reduced it by 31 eggs, winter pause caused a reduction of 24 eggs, broodiness 17 eggs, and late maturity 7 eggs.

The combined effect of several characters on the annual egg record in these 1220 pullets is of particular interest. The data are shown in Table 16.

TABLE 16.—RELATION OF FIVE DESIRABLE CHARACTERS TO ANNUAL EGG PRODUCTION IN RHODE ISLAND REDS. (*Massachusetts Agricultural Experiment Station*)

No. of desirable characters	No. of pullets	Per cent of total	Average egg production
0	....	..	...
1	10	1	125
2	69	6	157
3	393	32	188
4	439	36	224
5	309	25	252
Average	1220	100	215

The foregoing analysis of laying performance is suggestive rather than final. It suggests the kinds of building blocks out of which a good performance record is made, and the subdivisions which are likely to be important in selection. It is obvious that if a given female matures at an early age, lays at a high rate, has no pauses, and is a persistent layer, she will inevitably have a high annual egg record. This will be true whether we are able to understand the underlying genetics and physiology or not. But if such hens are to make up a high percentage of any flock, it will be because some breeder has delved deeply into the problem of selection and improvement.

The seasonal distribution of egg production may vary widely among hens making the same total annual egg record. This, together with the well-known influence of many environmental factors on egg production, makes it clear that (1) there is no simple formula for explaining the inheritance of egg production, and (2) the heritability of egg production is not very high.

When we say that the heritability of egg production is not very high, we are simply saying that there is no accurate way of sorting the genetically high producers from those which laid well mainly because the environment was such that they could do so, or the genetically poor layers from those which had low records because of an unfavorable environment. It means that our basis of selecting breeding stock must be something other than mere evidence of having laid 300 or more eggs in twelve months. Family selection and the progeny test must be brought into play if we are to have any success in identifying individuals with desirable genotypes. But the opportunity is there as long as there is any appreciable heritability left for the character in which we are interested.

HATCHABILITY

The final character chosen for discussion in this chapter is hatchability. By definition, it is usually taken to mean the percentage of

fertile eggs which hatch under artificial incubation. It is influenced by many things such as age of breeding stock; rate of egg production of the breeders and the rations they have been fed; season of year; size of eggs; character of egg shells; length of holding time after laying, and conditions under which eggs for hatching are held; temperature, humidity and other conditions in the incubator; as well as by genetic influences working through the hens that laid the eggs or the males that fertilized them.

The emphasis here is on the environmental rather than the genetic influences. It is true that there are some 16 lethal genes which either reduce or prevent hatching. It is also true that the indirect effect of certain other genes which influence egg size and shell quality may reduce the percentage of eggs which hatch. But by and large, the problem of improving hatchability is a problem of improving the environment. Hatchability for a given flock in any given season may be improved by eliminating individual hens which show poor hatchability early in the season, but it is futile to select as future breeders hens which give high hatchability, and sons of such hens, with the expectation that average hatchability of a flock will thereby be greatly improved by reason of inheritance. Some writers have referred to specific genes for hatchability, but all available evidence supports the view that heritability of this character is very low. Except for selection against the lethals, and against such indirect effects as large and small egg size and poor shell texture, genetics has little place in the improvement of hatchability. The problem of rations which are nutritionally adequate, and the management methods which help to insure a high percentage hatch will be discussed in later chapters.

SYSTEMS OF BREEDING

Only a small fraction of all the chickens on farms and ranches ever become a part of any planned system of breeding. Most of them, however, are influenced in some degree by the systems in use by breeders, and in particular by the selection and improvement procedures carried out by commercial hatcheries. Seldom is any one system used exclusively by a breeder, and it is probable that the most successful breeders make use of all the accepted systems from time to time and in combination.

Inbreeding.—A simple and easily understood definition of inbreeding is that it involves the mating together of closely related individuals. The closest inbreeding which the poultryman can use is continued brother × sister mating for several successive generations. A lesser degree of inbreeding results from the mating of father × daughter, mother × son, half-brother and sister, or cousins.

Some degree of inbreeding is essential to the development of uniform stocks. Close inbreeding makes for greater uniformity

but, since undesirable genes as well as desirable genes are concentrated in the inbred line, the overall effect is frequently disappointing. Close inbreeding by itself is, therefore, not often profitable.

It must be clearly understood that maintaining a closed breeding flock, even if the total number of females in any one year is no more than 100, is not necessarily inbreeding in the accepted sense. So long as the breeders are chosen more or less at random, and several males are used each year, there is very little risk of any sort of trouble which can be ascribed solely and specifically to inbreeding. On the contrary, the success of many breeders can be attributed in part to the fact that they have chosen to follow the closed flock plan.

Outbreeding.—Outbreeding is essentially the mating together of individuals which are less closely related than the average of the flock with which the breeder is working. The poultryman often speaks of it as introducing new blood. With flocks in which several desirable characteristics are well established, it should be done very cautiously, if at all.

There are numerous instances in which a strain has been ruined by the unwise introduction of new stock in such a manner as to involve the whole flock. Test matings, involving a small fraction of the flock, should always be made before risking the entire breeding program, assuming that one has highly productive stock with which to start.

Outbreeding often increases the average performance of the individuals in the next generation—average egg production, for example—so that the breeder may think he is making real progress. The trouble is that the breeding value of his best birds is lowered by making them more heterozygous than they were before, thus lessening the chances of being able to carry on their good qualities to the next generation. If the stock is not to be used for future breeding, there is no objection to such a change in genetic make-up.

Crossbreeding.—For the same reason that outbreeding frequently improves the average performance of the first generation, crossbreeding of totally unrelated breeds sometimes produces rather startling results. The new combination of genes often results in a high degree of heterosis or hybrid vigor. This usually is apparent in rapid growth, uniformity, and sometimes in increased egg production. Whatever is gained in these lines with respect to individual performance is offset by lowered breeding value. Hence crossbreeding is most useful when applied to the production of stock which is to be grown for meat purposes, or kept no more than a year or two for egg laying, and then sold without any attempt to use it for breeding.

Crossing of Inbred Lines.—There has been much recent interest in the crossing of highly inbred lines belonging to the same or different breeds, on the supposition that such a procedure might duplicate for poultry some of the known advantages of hybrid corn. The

chickens so produced are commonly referred to as hybrids, and the system of breeding used is often called hybridization.

When highly inbred lines from two different breeds are crossed, the resulting chicks have a much higher degree of heterozygosity than do chicks from a mating between random samples of the same two breeds. This increases the predictability of results, whether good or bad, so that one can make additional matings between the same two inbred lines with the expectation of getting substantially the same results.

Present commercial practice is to make use of four-way crosses involving two inbred lines within each of two breeds. The lines within each breed are crossed, and these two crosses are then brought together to produce the commercial hybrid chick. Production and maintenance of the inbred lines is costly, and many of them have to be discarded after trial because they do not combine well with other lines.

The egg production of such hybrid chickens as have been commercially available has been good enough to make certain that still more of them will be produced. It is still too early to say whether such stock will consistently out-perform equally well-bred pure stock. Much additional research is needed on the subject.

Reciprocal Recurrent Selection.—As already mentioned, close inbreeding gradually makes a population more homozygous for both desirable and undesirable genes. Very frequently the concentration of unfavorable genes puts an end to the inbreeding program, at least in some of the lines. In fact there is some reason to believe that continued brother × sister matings for several generations are possible only because of natural and controlled selection *against* this very homozygosity, so that the eighth or ninth generation is not as closely inbred as the calculated coefficient of inbreeding would indicate. It may even be that a certain amount of heterozygosity is a basic essential of being alive. Many geneticists are of the opinion that the best performance comes not from individuals which are homozygous for a large number of desirable genes, but rather from individuals which are somewhat if not highly heterozygous.

The concept of increased heterozygosity as a condition favorable to high egg production has led to another idea which some breeders are attempting to apply to poultry. It is to discover and measure the "combining ability" of both strains and families in terms of strain or breed crosses. Within a breed it means finding two, three or four strains or lines which combine well together to give production better than can be obtained from any one of the strains alone. Each strain would then have to be continued by matings within its own stock, but with individuals used in such matings selected on the basis of their ability to combine well with two or more of the other lines or strains. Because three or four such strains would no doubt be combined in various ways, and because selection would be

based on combining ability rather than on family performance within each strain, this plan of breeding is being referred to as reciprocal recurrent selection. It is too new to be properly evaluated, but it has interesting theoretical possibilities. It is mentioned here primarily to indicate that poultry breeders are keenly interested in any and all techniques which offer some promise of increasing the effectiveness of selection.

Making a Breeding System Work.—No matter what system is used, the breeding value of a given individual must be judged either from its own performance or from the performance of its relatives. This means that the breeder must use great care to avoid confusing the effects of environment with those of heredity. Variations caused by environment can be very large in such characters as egg production, and they can be very important economically, but they do not change the hereditary makeup of the individuals so affected. They are therefore not transmitted to the next generation. They can be reproduced only by repeating the environmental conditions which produced them originally.

Improvements brought about by heredity, on the other hand, tend to be permanent, and the cost of making them may be returned many times over in future generations. This means that different characters in any selection program should be given emphasis in proportion to both their heritability and their economic value.

It is important to remember that while the gene is the actual unit of inheritance, the individual fowl is the smallest unit that can be saved or rejected for breeding purposes. This is bound to temper one's judgment as to the value of inbreeding, for example, except for specific purposes. Inbreeding is, in fact, a much stronger force for lowering annual egg production than selection is for increasing it. The effect of close inbreeding in a small flock could not be overcome by any amount of selection pressure in the direction of increased egg production.

Successful breeding systems of the future will no doubt be applied principally to large flocks which consist of many fairly large families of full or half sisters. They will be designed to take full advantage of all known methods of improvement, including some complex selection indexes. They will also include careful consideration of such things as the optimum proportion of pullets to older hens and of cockerels to older males in the breeding flock, because these things are important in determining both the intensity of selection for desired characters and the interval between generations. Selection methods are discussed in more detail in the next chapter.

CHAPTER 4

SELECTION AND IMPROVEMENT

SELECTION, as used in connection with breeding, refers to the choosing of parents for the next generation. Its skilled performance is the foundation of constructive breeding practice. One should remember that selection will be operating no matter what system of breeding is used, even though in the simplest case it may be reduced to mere chance. Furthermore, selection can not change or alter any genetic process any more than will trap-nesting or pedigree breeding. All that it can do, if successful, is change the gene frequency by preventing the poorer individuals from being hatched, and thus carry the breeder more rapidly in the direction of his ultimate goal.

SELECTION METHODS

Selection of individual males and females for breeding may be based on:

1. The past—in which the pedigree of the individual is examined for several preceding generations.
2. The present—in which the appearance or performance of the individual and its sibs (sisters and brothers) is used in making final judgment.
3. The future—in which the breeding worth of the individual is judged by the appearance or performance of its descendants, usually only its sons and daughters.

Two or more of these bases may sometimes be used in combination, especially the second and third. The constructive breeder attempts by selection to segregate individuals which are pure for certain desirable genes and, through intelligent mating, to assemble in new individuals still more desirable combinations of genes.

Pedigree Selection.—A good individual with a good ancestry is to be preferred to an equally good individual with a poor ancestry, but it should be emphasized that a good ancestry only improves the chances for desirable breeding performance; it is no guarantee of such performance. Since genes and chromosomes occur in pairs, and are halved for any individual in each generation, it is immediately apparent that a particular remote ancestor can have very little influence on the genetic makeup of an individual which is being considered in selection. It can be shown by suitable calculation that an ancestor which appears but once in the tenth preceding generation

will have contributed less than one-tenth of one per cent to the total genetic makeup of the individual. A similar ancestor in the fifth generation will have contributed, on the average, only a little more than 3 per cent.

Pedigree selection is of value in a broad sense in that one would certainly choose a breeding cockerel whose dam had laid 250 eggs in preference to one whose dam's record was only 150. But one

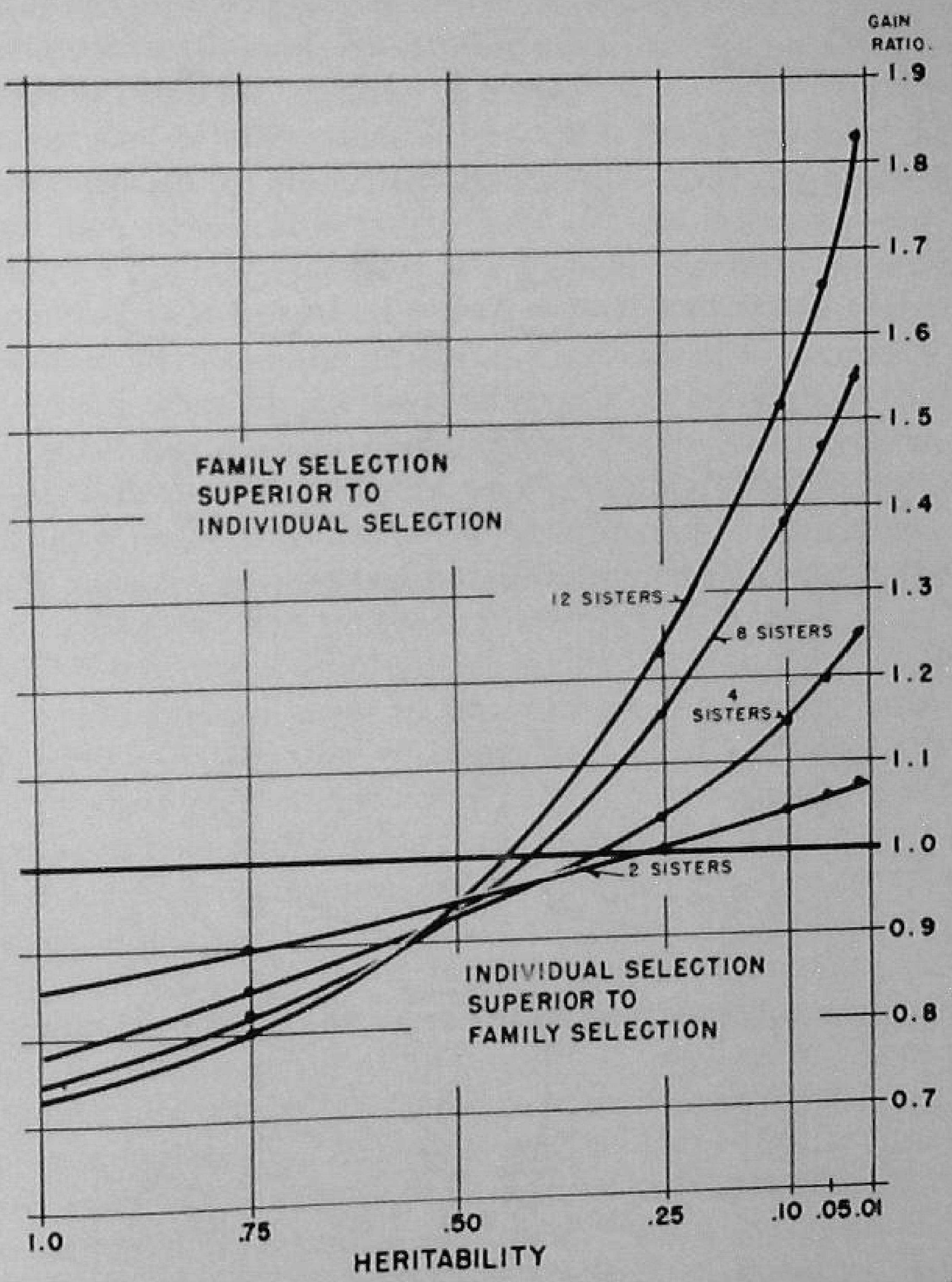


FIG. 43.—As heritability decreases, family selection becomes more and more important, especially when large families of full sisters are available. The curves show the ratio of expected gains from family selection alone over individual selection alone. (*Adapted from Lerner.*)

should also remember that two cockerels from the 250-egg hen may give widely differing performance as measured by the egg production of their daughters. Furthermore, a difference between 250 eggs and 150 eggs in a dam's record may be important in selection, whereas a difference between 275 and 250, or even between 300 and 2 may not.

Individual or Mass Selection.—Mass selection is predicated on the assumption that the appearance or performance of an individual can be taken as an indication of its breeding worth. For some characters this assumption is correct, and selection is then very simple. All one need do is identify the desired individuals with respect to some reliable measure of the character in question. For

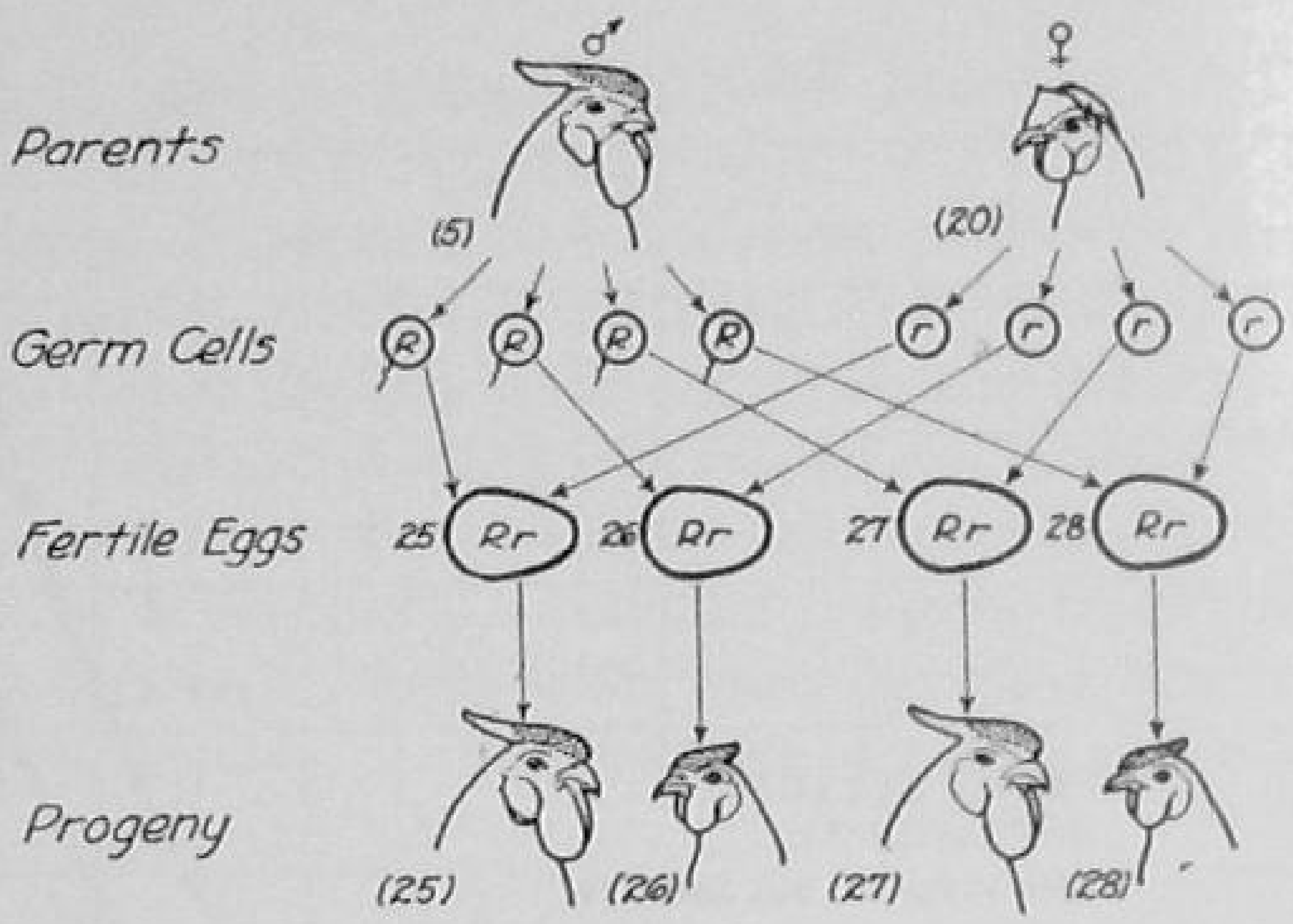


FIG. 44.—Showing the test for purity of a simple character. The male indicated here is pure for rose comb. Compare with Figure 45.

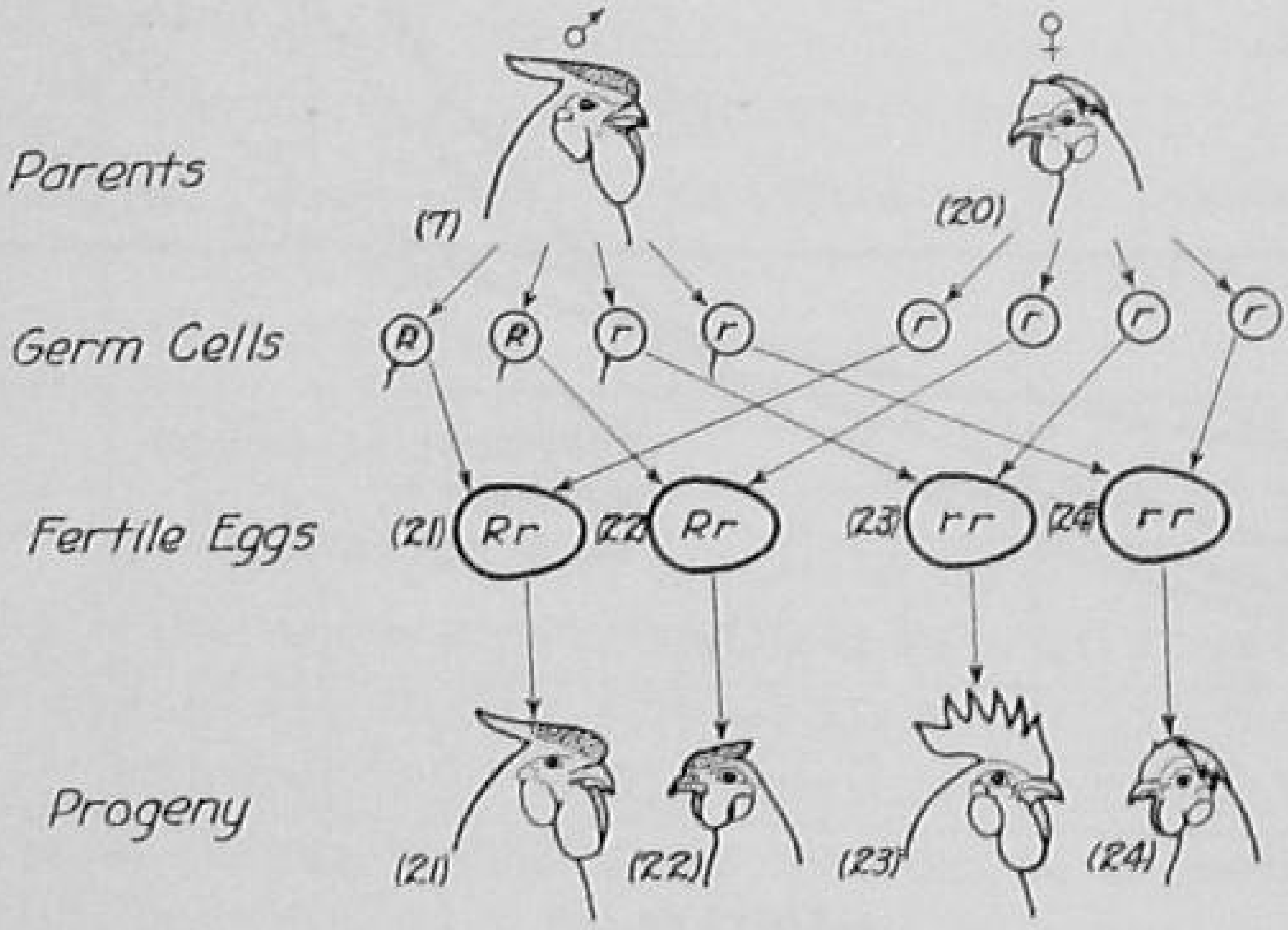


FIG. 45.—Showing the test for purity of a simple character. The male indicated here is not pure for rose comb. Compare with Figure 44.

many characters, however, and especially for those of economic importance which are influenced by many different genes, the assumption is so far from the truth as to be completely misleading. This arises not only because the presence of many genes makes their enumeration and recognition difficult, but because the effect of environment on the expression of the genetic character may be and frequently is very great.

Mass selection, based on phenotypic performance, may be effective through the low to medium range of a given quantitative character and quite ineffective in the upper range. Egg production is a good example. There can be no doubt about the effectiveness of individual or mass selection in improving average egg production up to 160, 180, or perhaps 200 eggs per pullet per year—the exact limit depending both on the sort of stock with which one is working and the environment under which it is kept. But continued dependence on mass selection can only lead to disappointment when it ceases to bring any further progress.

A great deal of improvement in poultry flocks has been the result of widely applied mass selection practices, particularly in the elimination of such undesirable individuals as slow growers, poor layers, and those which detract from a reasonably uniform appearance of flocks. Many flocks can still be improved by this method of selection, but as performance moves up the scale it is necessary to use more refined selection methods or accept something less than maximum performance as the end and aim of a breeding program.

Family Selection.—Modern breeding methods involve a great deal more than a detailed record of the performance of individuals. They consider rather the extent to which individuals reflect the performance of a family. The distinction is important. Sons of a 240-egg hen which was one of eight sisters laying between 230 and 260 eggs each are much more likely to transmit desirable genes for egg production to their daughters than are the sons of a 280-egg hen whose sisters finished the year with records of 190 to 230 eggs. But there is still no assurance that the particular son of the 240-egg hen chosen to head a new breeding pen will be able to equal the breeding performance of his sire. Hopes may be built upon ancestry, individuality, and sibs, but the only sure basis for forming a judgment concerning the ability of an individual to transmit genes for desired characters to most or all of its progeny is breeding it. This part of family selection is usually referred to as the progeny test.

By progeny testing is meant a careful analysis of the results secured from various matings in order that future matings may be made with greater assurance of success. Any mating that has given unusually good results should be repeated or, in terms of today's procedure on many breeding farms, continued. The progeny test is also used for the purpose of distinguishing between individuals which are homozygous and those which are heterozygous for some simple character such as rose comb or white skin color. Only one single-comb chick is needed from a mating of two individuals with rose comb to show that *both* parents are heterozygous for rose comb. Similarly, if any of the offspring of two white-skin parents have yellow skin, both parents must be heterozygous for skin color. When it is desired to check a given male to find out whether he is homozygous for rose comb, the simplest procedure is to mate him with a

few single-comb hens. If even one chick hatched has a single comb, the male is heterozygous. If, on the other hand, there are no single combs among as many as twelve or fifteen chicks, one can be practically certain that the male is homozygous.

More often, however, a breeder is concerned with the progeny test as a measure of breeding worth in respect to some quantitative character such as annual egg production, egg weight, mature body weight of females, or survival through a full year of egg production. This calls for records which are sufficiently complete to provide the necessary measures. Just what they are will depend on the particular characters under observation, but certain details are necessary in any case. Some of these are indicated in the following section.

Fig. 46.—Trapnesting is speeded up by the use of a portable microphone and a wire recorder. Later the spool of wire is played back in the office where permanent egg records are kept. (*Courtesy of Heisdorf and Nelson Farms.*)

BREEDING AND PERFORMANCE RECORDS

From the preceding discussion of the bases of selection, it should be clear that complete breeding and performance records are essential items in the progressive production-breeder's equipment.

Steps in Keeping a Complete Record.—The steps in keeping a complete record are: (1) marking prospective breeders; (2) recording egg production; (3) recording the matings made; (4) identifying the eggs to be hatched; (5) pedigree hatching; (6) recording fertility

Fig. 47.—When trapnesting is done from a central alleyway, hens can be returned to the proper pen through a convenient trap door. (*Courtesy of American Poultry Journal.*)

and hatchability; (7) marking and recording the chicks; (8) recording livability, rate of growth, rate of feathering, and the like; and (9) making family summaries.

Record systems may be simple or complex, depending on the number of characters under observation, but an elaborate set of records is of little real value unless the data are carefully analyzed.

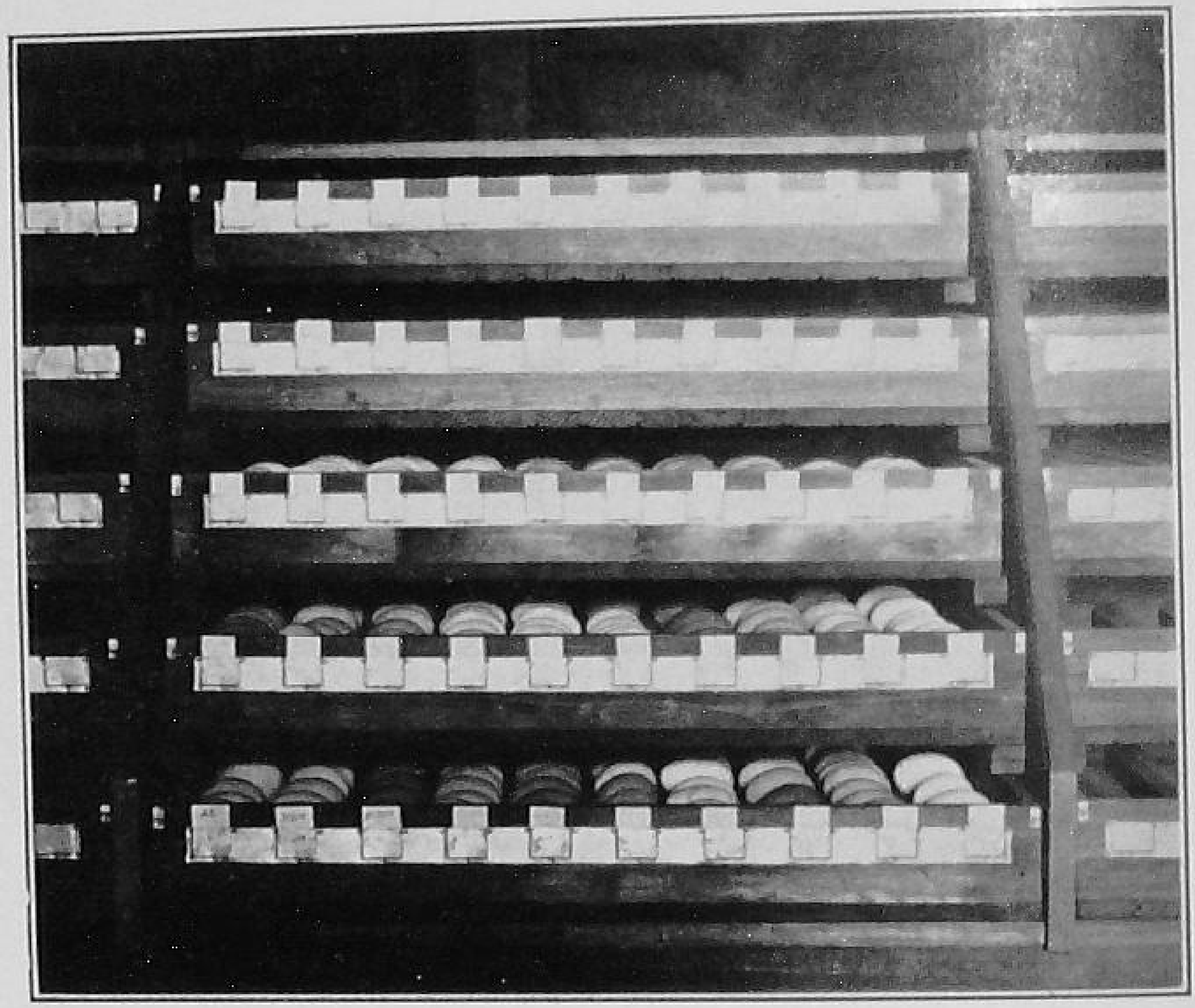


FIG. 48.—A convenient type of pedigree egg cabinet. One section of five trays will accommodate the eggs of fifty mated females. (*Courtesy of H. D. Goodale.*)

FIG. 49.—The eggs from each hen are hatched in a separate basket or compartment so that an accurate record can be kept of the parentage of the chicks. (*Courtesy of U. S. Department of Agriculture.*)

A few simple records well kept and carefully studied will be much more helpful than a complete set which involves so much work that there is no time for its analysis.

Record forms may be purchased, but since no one system of records can be best for all purposes, the breeder will usually do better by developing such forms as best suit his own particular needs.

Making Use of Records.—The records to be kept and the use to be made of them will naturally vary with the objectives which the individual breeder has in mind. The following suggestions will serve as a guide in using family, individual, and progeny test records when the breeding objective is high production of market eggs.

Minimum standards for birds to be saved as breeders should be set for each factor considered, or all birds may be given a grade of A, B, or C on each separate factor and on overall breeding value. The standards may be raised from time to time as the flock improves. Those indicated here are for purposes of illustration only.

Factors Known Prior to the Hatching Season.—Certain factors can be measured early in the life of the individual, while others must wait for performance of its progeny. Some of those in the first class are:

(*a*) Family size (5 or more full sisters).

(*b*) Family egg production (hen-housed average of 185 eggs or better—also known as the production index).

(*c*) Family egg quality (size—2 ounces within sixty days from first egg; color, shape, and interior quality standards as desired).

(*d*) Family survival to specified age (90 per cent to six months of age; 85 per cent in laying house, before any culling).

(*e*) Family record of physical characters (body weight, standard disqualifications, etc.).

(*f*) Hen's individual record of egg production.
Early maturity—two hundred and fifteen days or less.
Non-pause—no winter pause of seven days or more.
Non-broodiness—no broody periods.
Intensity—clutch size of 3 or more eggs, or 50 eggs in sixty consecutive days before March first of pullet year.
Persistency—late molt, and still laying at three hundred and fifteen days from date of first egg.

Factors Based on Hatching Season and Progeny Test.—Although preliminary selection of breeders must nearly always be made before any record of progeny performance is available, a final check on the value of a breeding bird can be made only after its offspring have had an opportunity to perform in the laying house. Some of the additional factors which can then be applied are:

(g) Hen's own record of fertility (90 per cent or better).
(h) Hen's own record of hatchability (85 per cent or better)
(i) Number of daughters raised.
(j) Rate of growth of chicks.
(k) Rate of feathering of chicks.
(l) Daughters' average egg production.
(m) Daughters' average egg quality.
(n) Daughters' record of survival.

SELECTION IN PRACTICE

The foregoing discussion may suggest to some persons that breeding for egg production can easily be reduced to a matter of keeping individual egg records, assembling them into family averages, choosing the better families for breeding, and by so doing to keep on improving flock average egg production year after year. Unfortunately, it is not that simple. Perhaps the chief reason why it cannot be that simple is that no poultry breeder can afford to be satisfied with improving a single trait such as number of eggs. His stock must be of acceptable body size and general appearance; it must live well; the chicks must grow rapidly and feather properly; and the eggs laid by surviving pullets must be of suitable size, shape, color, shell texture and interior quality.

Suppose, for illustration, that a poultryman is satisfied to use in his breeding program any sires which, on the basis of family performance, are above the average of his entire flock. Only about half of all the sires can be above average in any measure of family egg production, for the other half must be below. Similarly, only about half can be above average in respect to family egg size. But the chance for a given sire to be above average in both respects becomes $\frac{1}{2} \times \frac{1}{2}$, or $\frac{1}{4}$. That is, only one in four can be expected to excel in both characteristics. If, now, we add a requirement that a sire excel also in respect to suitable measures of body size, interior egg quality and shell color, we reduce the mathematical chance of finding such a sire to 1 in 32. A small breeder may not even have a total of 32 tested sires in any one season.

There are other important characters for which selection should be practiced. For instance, no sire should be used which did not come from a family of some reasonable minimum size, and he in turn must have a reasonable number of daughters as a basis for evaluating his own breeding worth. And all will agree that choosing males which merely exceed the *average* in respect to the desired qualities does not constitute very rigid selection. If we say that the males chosen must be in the upper 25 per cent of the flock in respect to five different character measurements, then instead of finding 1 in 32, we can expect by chance to find only 1 in 1024(namely, $\frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} \times \frac{1}{4} \times \frac{1}{4}$). And if we set the requirement at the upper 20 per cent level,

we still further reduce the chances to 1 in 3125. At 10 per cent it becomes 1 in 100,000. This is just another way of saying that poultry breeding is difficult and complex, and that progress toward the upper physiological limit in terms of production performance is bound to be slow.

The preceding discussion should make it clear that if high average egg production is the chief aim of a breeding program, each additional character for which selection is made, if at the same time and to the same extent, automatically reduces the intensity of selection which can be applied to the main objective. In the example just used, if 10 per cent of the available males must be saved for breeding purposes, and if family average egg production is the only character considered, the top 10 per cent of the males can be chosen. But if two characters are considered, assuming no correlation between them, only about 1/10 of the males which qualify in the first character will also be in the top 10 per cent with respect to the second. Therefore the remaining 9/10 of the males which must be saved to provide the minimum total number will fall below the desirable standard in one or both measures.

If we select for as many as five characters simultaneously, provided they are not correlated and assuming that we want the best 10 per cent of all males as before, the intensity of selection for any one character is reduced a great deal further, actually to the equivalent of $\sqrt[5]{1/10}$. Hence it is very important when making selections not to give undue weight to those characters which are of minor significance. If a breeder feels that he must select for a certain shade of plumage color, in addition to perhaps five economically important characteristics, he must accept the obvious corollary that progress toward his main objective of high average egg production will be slowed just that much more.

Fortunately, there are some short cuts. A breeder may find it wise to concentrate on one or two characters at a time. He can use production to January 1 as his measure of egg-laying ability instead of insisting on full yearly records; he can use the median instead of the mean for measuring such family traits as age at first egg; he can breed from pullets instead of from older hens in order to get ten generations in ten years instead of only five. All of these will help because they save time, in terms of breeding progress, and because they enable a poultryman with a specified number of breeding pens to increase the selection pressure which he applies to his stock. But even when all these things are taken into account, poultry breeding today is big business. It calls for extensive facilities in the way of physical equipment, large numbers of fowls, and a great deal of labor both in the keeping of detailed records and in their analysis. Some breeding operations involve more than 500 small pens for flock matings headed by individual males. The larger breeding farms make extensive

use of punch cards and tabulating equipment in handling thousands upon thousands of individual records.

All of this has come about, not merely as expansion and growth, but in an attempt to discover and apply more refined and precise methods of selection to the business of increasing egg production. As pointed out earlier, poultry breeders have come a long way by the use of a common sense approach to the problem, so that a prospective purchaser of chicks or breeding stock today can obtain at nominal cost the kind of chickens which not so many years ago were known on but few farms in the country. But because better and better performance is demanded, breeders will continue to use all means at their disposal to reach still higher goals.

For many years, while egg production has been increasing from low to mediocre to good, the amount of variation traceable to heredity has been large enough to make selection—even mass selection—highly effective. Concurrently much has been learned about how to improve egg production performance by providing better environment. The stimulus of artificial light, the favorable effect of the best possible rations, the increase in fall egg production resulting from consistently early hatching, the construction of houses of a size and type which will conserve the heat energy produced by the hens themselves and so provide more comfortable winter quarters have combined to increase the opportunities for improving egg production through the influence of environment. An inevitable result has been that as mass selection approached the limit of effectiveness, the amount of individual variation traceable to environment increased. The indications are that in many of today's better bred flocks the heritability of egg production, that is, the amount of variation directly traceable to heredity, is no more than 30 per cent, and that the heritability of the production index, because it includes the effect of mortality, probably does not exceed 5 per cent.

This low degree of heritability does not mean, however, that poultrymen should discard all selection and breeding efforts to concentrate on methods by which egg production can be further improved through environment. It does mean that the individual has become of little importance in selection except as it helps to make up a family average, or as it is representative of a family with high average performance. It means also that further progress will be slow, even with increased selection pressure. And it means that as this continued progress is made, the heritability figure will decline still further as the barrier to increased egg production through genetic means is raised higher and higher. The detailed theory behind this reasoning is too intricate to be included here, but to the student of poultry genetics it is a fascinating subject.

Regardless of the breeding and selection methods used by specialty breeders, there are many thousands of flock owners who do no breeding but who, for economic reasons, are very much interested

in methods of separating high-producing hens from their low-producing flock mates. Routine culling of laying flocks means many dollars saved in feed which would otherwise be consumed by non-layers. In the following sections are given the essential facts about methods of estimating production ability from external examination and appearance of the fowls, without the use of trapnests.

ESTIMATING PRODUCTION QUALITY FROM EXTERNAL APPEARANCE

The Relation of Selection and Culling.—In actual practice the selection and culling of poultry should begin when the chicks are taken from the incubator and should continue as long as they live and make up a part of the flock.

Although frequently used as synonyms, the terms "selection" and "culling" are strictly opposite in their implication. Selection aims at progress. It is positive and constructive. It deals with the very cream of the flock, including at the most the top 25 per cent, and more commonly only the top 10 or 15 per cent.

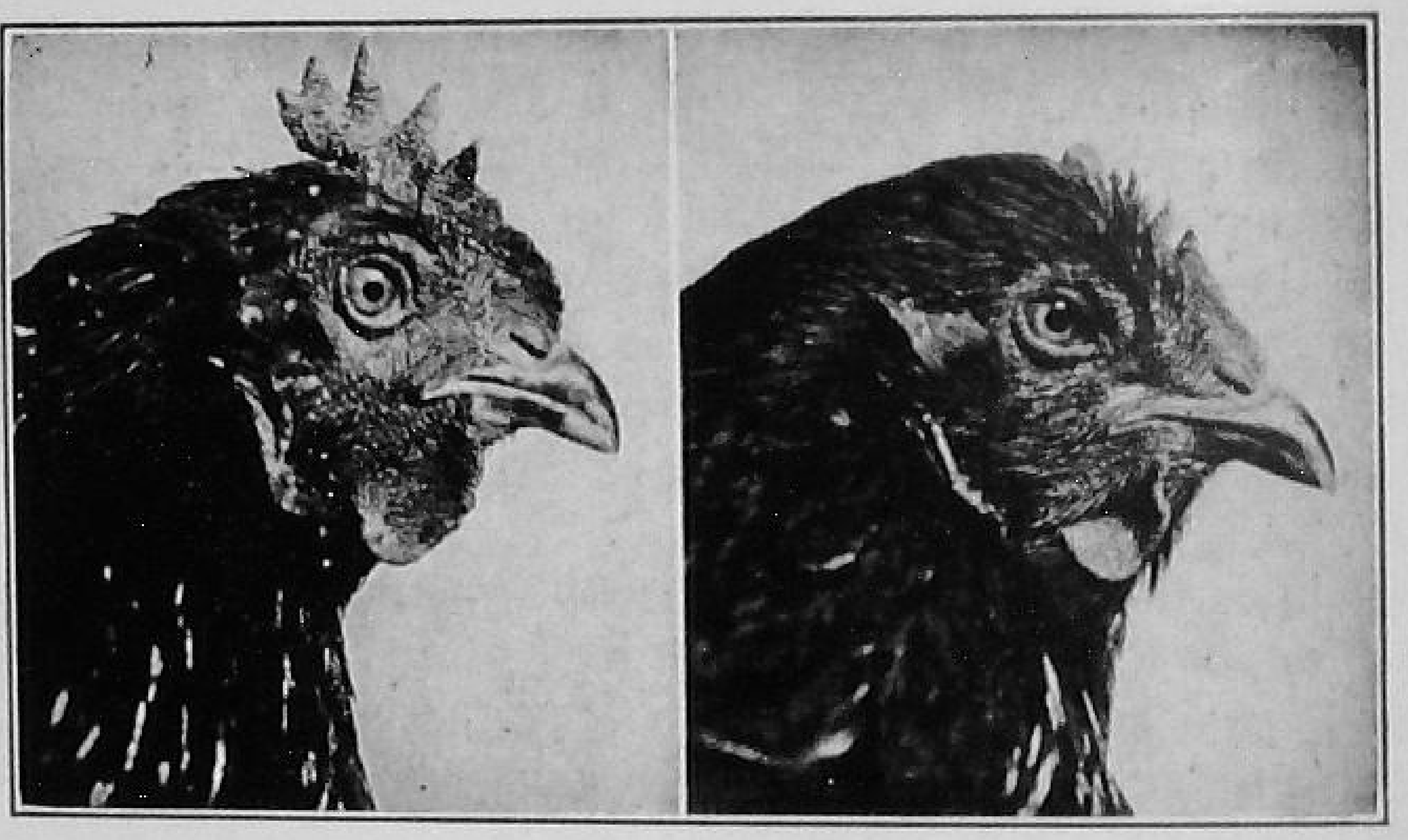
Culling, on the other hand, is negative, has no necessary relation to breeding, deals with the least productive fraction of the flock, and is aimed at the prevention of retrogression rather than at progress.

It is unfortunate that the term "cull" should have come to mean one thing to the poultry producer and quite another thing to the buyer of market poultry. In marketing practice a "cull" is an inferior product from a meat standpoint, whereas to the producer a cull hen is simply a non-layer or one that has made a low record. As the term is short and descriptive, it seems likely to persist in both usages, but the distinction between them should be clearly understood.

Physical Characters Related to Laying.—As applied to the laying flock, the judging of fowls for egg production really consists of two distinctly different phases, which in practice are nearly always considered simultaneously. These are (1) the separation of the laying from the non-laying hens with the object of disposing of the ones that have stopped for the season, and (2) sorting hens on the basis of their ability to lay eggs throughout the year.

It is significant that the second phase has to do largely with estimating past production, and that most of our knowledge in respect to the judging of laying ability is closely tied up with the fact that high egg production leaves its mark in the way of discernible physical characteristics. To the extent that a good hen in any one year tends to repeat the performance, the selection of high layers on the basis of past production has a commercial value that is not necessarily related to the breeding problem, though it is commonly used as a part of a general improvement program.

Head Type.—The appearance of the head is variable because of differences in size, shape and expression. Some of these differences are undoubtedly related to laying performance, and several different attempts have been made to arrive at more or less exact correlations in order that head types may be accurately classified and used as a basis for the estimation of laying ability. While this objective has not been, and perhaps never will be, wholly realized, it is entirely possible to group head types according to the degree of refinement, and to show some relation between this and the egg records. Hens with coarse, phlegmatic, masculine, or "beefy" heads are not likely to lay very many eggs. Those with clear-cut rugged, alert heads that are at the same time fine in quality, are likely to be among the best layers in the flock.



A *B*

FIG. 50.—*A*, The head of a high producer, 281 eggs in one year; and *B*, of a low producer, 106 eggs in one year. Note the contrast in appearance of the eye, and in fleshing of the face. (*Courtesy of Kansas Agricultural Experiment Station.*)

Body Type.—Type or shape of body is essentially a breed characteristic and, therefore, is directly the result of, and is influenced by selection. It is obvious that in order to lay for a long time and at a high rate a hen must have the capacity and ability to utilize large amounts of feed rapidly and efficiently. This means, among other things, that there must be ample room in the body cavity for the functioning of the vital organs. Further than this, there does not seem to be any reasonable basis for assuming a causal relationship between body type and egg production.

Body Changes.—When laying, a hen has a large, moist vent, showing a dilated, pliable condition in contrast to the puckered hardness of the vent of a non-laying hen. The abdominal region is enlarged in the layer, as compared with the non-layer. The pelvic bones move apart and become comparatively elastic and pliable.

In an individual that is not laying these bones almost come together just below the vent. The same individual when in full laying may show a distance of three or even four fingers' between them. The distance from the pelvic bone to the point of the keel (breast bone) is increased at the same time. These changes provide room for the passage of the egg, the enormous increase in the size of the ovary, with its several rapidly growing ova, and for the distention of the alimentary tract to accommodate large amounts of feed.

The rate of egg production is indicated in a measure by the relative softness and pliability of the skin and the thinness and elasticity of the pelvic bones. The subcutaneous fat of the abdomen is used up by laying, so that the abdominal skin of the heavy producer becomes velvety and the whole abdomen soft and flexible.

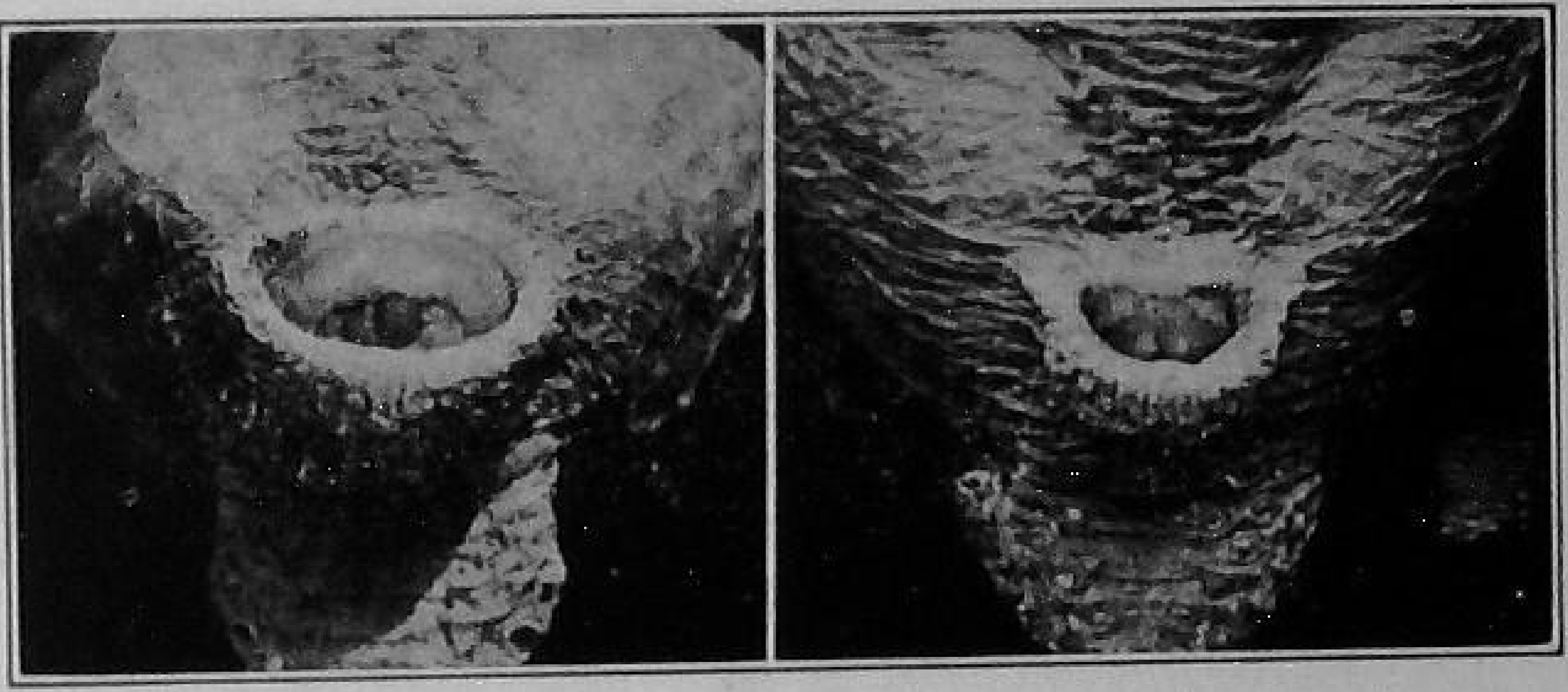


FIG. 51.—*A*, The vent of a laying hen, and *B*, of a non-laying hen. (*Courtesy of Kansas Agricultural Experiment Station.*)

The pelvic bones are also thin, tapering and elastic. In the non-layer they are likely to be thick, blunt and stiff, while the whole abdomen is surrounded under the skin with a layer of hard fat if the bird is on full feed.

Among the most valuable indications of the heavy layer are the refinement of the head and the closeness and dryness of feathering. The wattles and earlobes fit close to the beak and are not loose and flabby. The face is clean cut and rather thin. Puffiness in the face indicates meat rather than eggs. The eye is full, round and prominent as viewed across the tip of the beak. The high layer is trimmer in feathering than the poor layer, but after prolonged heavy production the oil does not keep the plumage so sleek and glossy. It becomes worn and frayed.

There is a close correlation between the relative size of the comb and wattles and ovarian activity. If they are comparatively large, full, smooth, hard and waxy, the hen is probably laying heavily; if the comb is limp the bird may be laying slowly; but if it is dried, shrunken and cold, she is not laying at all. When the comb is

expanding in advance of another period of production it often feels warm to the touch.

Pigmentation.—In those varieties showing yellow pigment in the subcutaneous fat, shanks (and earlobes in Mediterranean and Continental breeds), the pigment tends to disappear as laying progresses. The presence or absence of this pigment in the fowl or its eggs is directly correlated with the presence or absence in the feed of a carotenoid pigment called xanthophyll. For this reason a hen fed on a ration devoid of such feeds as yellow corn and green forage, which carry it in considerable amounts, might have the appearance of laying so far as pigment is concerned, though she had never produced an egg. The character of the feed the hen has been receiving should, therefore, always be considered in relation to her condition with reference to pigment.

When hens have feeds carrying an abundance of pigment, and the skin, shanks and beak are not normally pale as in the English breeds, the beginning of laying diverts all the pigment received in the feed to the ovary, where it finds its way into the developing yolks. The pigment of other parts gradually disappears as a result of the natural physiological change in the structure of the skin. It is not replaced as long as the individual continues to lay.

The vent loses its pigment very quickly so that a white or pink vent in a yellow-skinned variety usually indicates that the bird is laying, while a yellow vent indicates that she is not laying.

The eyering formed by the inner edges of the eyelids loses its pigment a trifle more slowly than the vent. The earlobes of the Mediterranean breeds bleach out somewhat more slowly than the eyering, so that in these breeds a white earlobe on a vigorous bird usually means a longer period of continuous laying than does a bleached vent or eyelid.

The color disappears from the beak next, beginning at the base and remaining longest at the tip. The lower part loses color more rapidly than the upper. With the average yellow-skinned bird a bleached beak means that laying has been in progress for from four to six weeks.

The shanks are the last to lose their color. Bleached shanks, therefore, indicate a much longer period of production than does the bleaching of the other parts. The pigment disappears from the front of the shank first and finally from the back. A bleached shank usually indicates continued egg production for at least fifteen to twenty weeks.

When laying stops, the pigment reappears in the several regions in the same order in which it disappeared. The relative rapidity of loss and regain in the various parts is probably correlated with the thickness of the skin, the pigment change being slowest where the epidermal covering is thickest. The fact that a given hen stopped laying two or three weeks back sometimes may be de-

termined by the fact that the tip of the beak is colorless while the base is yellow.

Molting.—The shedding and renewal of feathers normally occurs once a year, though it may occur in certain individuals twice in one year and, more rarely, only once in a period of two years. In the wild fowl it would have no relation whatever to egg production. Under the influence of domestication, however, the laying period has been gradually lengthened until it often overlaps the natural molting season.

FIG. 52.—A wing showing four new primary feathers partly grown. Note the axial feather. (*Courtesy of Kansas Agricultural Experiment Station.*)

Under the influence of the genes for high production, and particularly of those related to persistency and the length of the laying period, the natural tendency is for a good hen to continue to lay as late in the fall as she possibly can. The result is that she either molts late, *i. e.*, after her long laying period is over, or molts and lays at the same time. The low-producing hen, on the other hand, stops laying in July or August well in advance of the time that growth of a new feather coat must begin in order to put the hen in condition to resist the cold weather of winter.

Observation of the conditions that most commonly occur in laying flocks has led many persons into two faulty conclusions with regard to molt. One is that the onset of molt is a cause of the

cessation of laying, and the other is that hens never lay and molt at the same time. The facts seem to be, rather, that a hen molts late because she lays late, and that hens bred for continuous production at a high rate not only may, but often do, lay and molt at the same time. This latter condition probably does not occur except when a hen is increasing, or at least maintaining, her body weight.

The order in which the different sections of the fowl lose their feathers is fairly definite. The usual order is head, neck, body (including breast, back, and abdomen), wing and tail. Not only this, but there is a high degree of regularity about the order of molt within the several sections. The wing primaries, for example, begin to drop before the secondaries. The first primary to be shed is the inside one, next to the axial feather, and the remainder are shed in succession until the last one to be dropped is the outermost primary near the tip of the wing.

The order of molt of the secondary feathers is not so regular as that of the primaries, but the most common order, when the secondaries are numbered from the axial feather toward the body, has been reported as 11, 12, 13, 14, 10, 2, 3, 4, 5, 6, 7, 8, 9, 1. The axial feather is dropped at the same time as the secondary next to it.

In addition to being a late molter, the high-producing hen is also likely to be a rapid molter. Extensive observations have shown that there is no difference in the rate at which high-producing and low-producing hens grow new feathers, but that there is a decided difference in the rate at which the old feathers are shed. In no instance did an individual primary feather become completely grown in less than six weeks, and some feathers required seven weeks to complete their growth. The feathers made about 20 per cent of their growth in each of the first three weeks, and from 12 to 15 per cent during each of the second three weeks.

The rate of laying is not materially affected by the molt, in the case of hens that lay and molt at the same time, but the rate of molt is slowed up by production. The net result is that the advantage gained by the late molter, as measured by length of the period of non-production, is due, not to differences in the number of feathers dropped or to the rate of growth of an individual feather, but to the fact that two jobs are performed at one and the same time.

It should be remembered also that time and rate of molt are influenced to a considerable extent by weight and physical condition of the hens, and by environmental conditions including feeding and management.

Temperament.—A good layer is more active, more alert, and yet at the same time more easily handled than a poor layer. She is among the first off the perch in the morning and among the last on it at night. When not on the nest she is busy and business-like, scratching or ranging in an eager search for feed. The great layer is a bird of a seldom satisfied appetite.

Applying the Theory in Practice.—From what has preceded, it should be fairly obvious that any method which will identify the hens that (1) begin to lay at an early age, (2) lay at a high rate without pauses of any sort, and (3) continue to lay late into the fall at the end of their laying year, will automatically select the most productive hens in the flock. One method of accomplishing

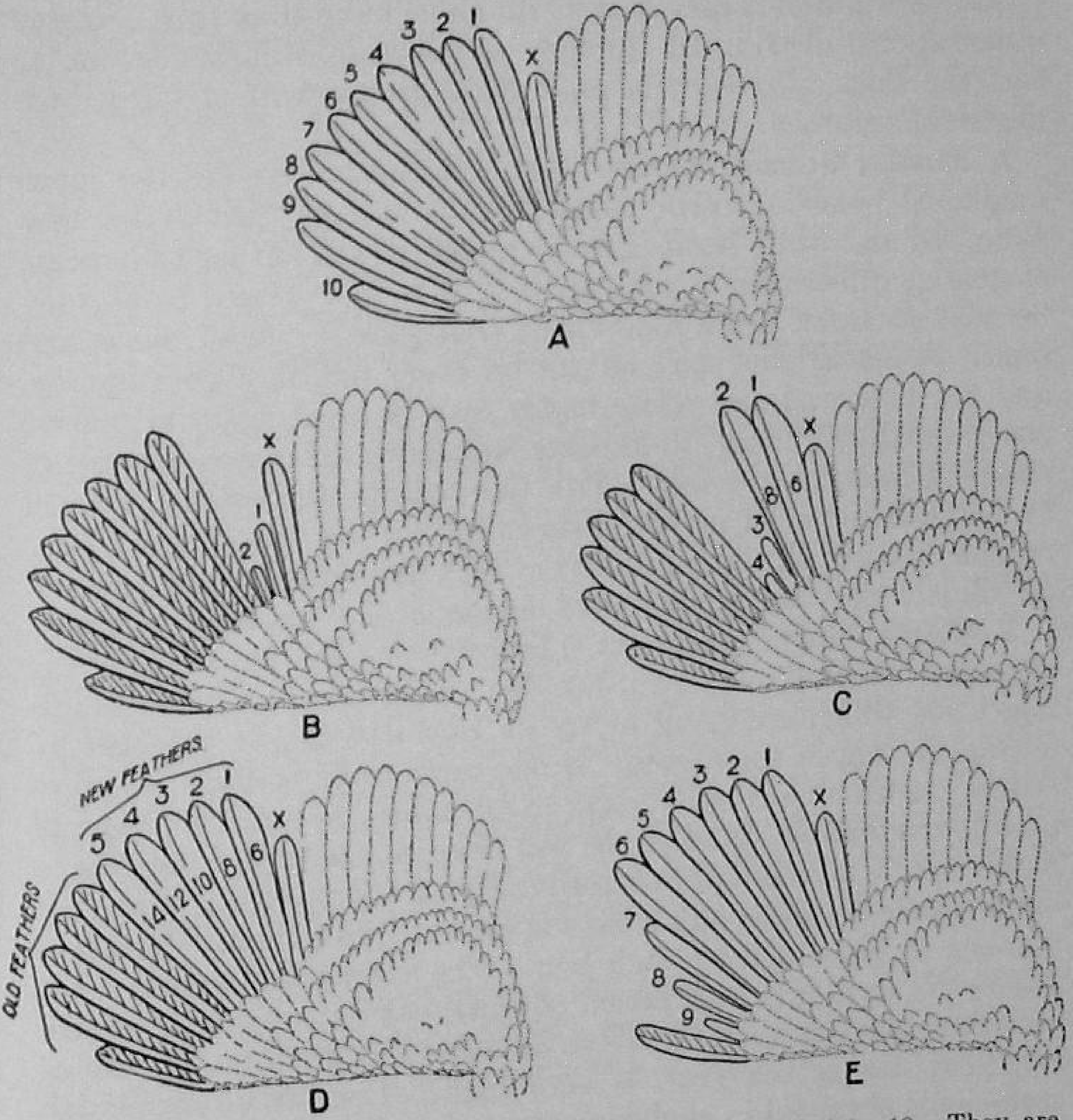


FIG. 53.—*A*, a normal wing showing the primary feathers, *1* to *10*. They are separated from the secondaries (shown in dotted outline) by the short axial feather, *x*. *B*, the beginning of a wing molt. *1* and *2* are new feathers growing in. *C*. an eight-week molt. Elapsed time in weeks is indicated on each feather. *D*, an unusual instance in which only five primaries were molted. *E*, a wing as it appears near the completion of a normal molt. (*Courtesy of Kansas Agricultural Experiment Station.*)

this objective is to use trap-nests all through the year. It is only by this means that we have been able to find out the things that are known about selecting hens for egg production.

In practice, however, it is usually not feasible to run trap-nests throughout the year, and the flock owner is compelled to depend

upon judgments that, in turn, are based upon his observation of the external physical characteristics that have just been discussed. If he is interested merely in getting rid of the poorer individuals in order that they may be replaced with pullets, a single sorting of the flock in the month of September may be all that is required. If, on the other hand, he is interested in making as accurate a selection as possible in order to save the best of the flock for breeding purposes, he will find it necessary to do much more than this. Several observations, distributed throughout the year, will enable him to sort the flock into various production groups with a fairly high degree of accuracy.

A Banding Scheme May be Used.—If the pullets are not given numbered bands, colored celluloid bands may be used as markers. Blue, red and white bands may be placed on the left leg to indicate successive differences in time of starting to lay. Green bands may be used to mark those individuals that show a winter pause and molt. A black band may be put on every hen that goes broody, and the blue, red and white bands may be used again in reverse order, on the right leg, to indicate successive differences in time of stopping to lay in the fall. With this scheme, the entire flock will be handled some six or seven times during the year, and a very reliable index of the laying ability of each individual will be secured. It will lack only the quantitative character of a trap-nest record.

A Substitute for the Trap-nest.—In discussing the formation of the egg it was pointed out that if hens are examined early in the morning, those which are going to lay on that day can be detected by feeling the egg in the uterus. If one cares to go through this procedure on three successive days each month, keeping a record of each individual hen handled, he will have, at the end of the year, a highly accurate record of the relative laying ability of the hens that make up the flock and also a basis upon which to estimate the actual number of eggs laid by each hen. The correlation between the number of eggs laid in a period of thirty-six days made up of the first three days in each of twelve months, and the total number of eggs laid during the year, is very high. The actual correlation coefficients obtained in analyzing one series of records were:

White Leghorns	+0.897	±0.007
White Wyandottes	+0.939	±0.007
Rhode Island Reds	+0.874	±0.011
Barred Plymouth Rocks	+0.858	±0.017

Disturbing Factors.—No matter what method is used in attempting to apply the theory of production judging to practical use, it should be remembered that even under the most favorable conditions some mistakes will be made. The inevitable biological error is considerable and, though there is much of practical value in the whole plan of selecting laying hens on the basis of external physical

characters, it is futile to attempt to accomplish worthwhile results by the use of some one or two characteristics alone.

THE NATIONAL POULTRY IMPROVEMENT PLAN

The National Poultry Improvement Plan became operative July 1, 1935. It is administered cooperatively by an official state agency in each of the cooperating states and the Bureau of Animal Industry of the U. S. Department of Agriculture. Authority for an official stage agency to administer the plan within the state is a memorandum of agreement between it and the Federal Bureau of Animal Industry. The state agency directs, supervises, and is responsible for flock selection, testing for pullorum disease, flock and hatchery inspection, and other local administrative work involved in the operation of the plan. The Bureau of Animal Industry is responsible for coordinating the program among the cooperating states.

The objectives of the plan are to improve the breeding and production qualities of poultry, and to reduce losses from pullorum disease. The procedures being used for the accomplishment of these objectives are: (1) Improving the efficiency of production of eggs and poultry meat by the general application of better breeding improvement practices; (2) reducing the losses of chicks from pullorum disease and improving the viability of poultry through better sanitary practices in breeding flocks and hatcheries; (3) the use of official terminology in the identification of breeding stock, hatching eggs, and chicks with respect to quality; and (4) the establishment of an effective cooperative program through which the best results from scientific research and practical experience can be most readily applied to the improvement of poultry and poultry products.

Complete details regarding the plan are available in Miscellaneous Publication 300 and Supplements, and Miscellaneous Publication 317, issued by the U. S. Department of Agriculture, Washington 25, D. C.

CHAPTER 5

INCUBATION

With the rapid growth of the hatchery business, fewer and fewer chicks have been hatched on the farms where they are grown until about 95 per cent of all chicks raised, either as farm chickens or as commercial broilers, are now bought as baby chicks. The breeding flocks which supply the hatching eggs are nevertheless widely distributed on farms, and it is therefore important for any student of poultry production and management to know something of the factors which influence hatchability, especially those which operate before the eggs are placed in incubators.

SELECTING EGGS FOR HATCHING

There are certain characteristics of individual eggs which are known to interfere with hatchability. Selection against these conditions will be effective in terms of the immediate hatching percentage, without regard to any considerations of heredity.

Workers at the Beltsville Agricultural Research Center selected from 47,950 eggs, by candling, those which had any one, but only one, of eight different defects. These eggs were incubated weekly over a period of one year, and the hatching results compared with those for control eggs which showed none of the defects and were therefore considered normal. Eggs showing two or more defects were excluded from the study.

The percentage hatch of fertile eggs was 80 for small eggs (45 grams or less), 72 for eggs containing large blood spots, 71 for extra large eggs (65 grams or more), 68 for eggs with air cells located in positions other than the blunt end, 53 for slightly cracked eggs, 49 for misshapen eggs, 47 for eggs with rough or thin shells, and 32 for eggs with loose air cells. These figures are to be compared with a a percentage hatch of 87 for the control eggs, which ranged in size from 50 to 59 grams and had none of the specified defects.

Hereditary differences in egg shell quality are responsible for wide variation in the loss of weight by evaporation of moisture from eggs during incubation. This is important from the standpoint of both hatchability and the keeping quality of eggs for market purposes.

There is some evidence to support the opinion that dark brown and medium brown eggs hatch better than light brown eggs from the

the same flocks, but this may be due in part to the tendency for eggs of light color (among brown eggs) to have rough, thin or porous shells.

Breeders who want to hatch as many eggs as possible from hens with known records, rather than from pullets, are usually faced with the problem of large eggs and their known lower hatchability when incubated along with medium or small eggs. If enough large eggs are being used to make it worth while, they can be set twelve hours ahead of the pullet eggs. It is still better, from the standpoint of

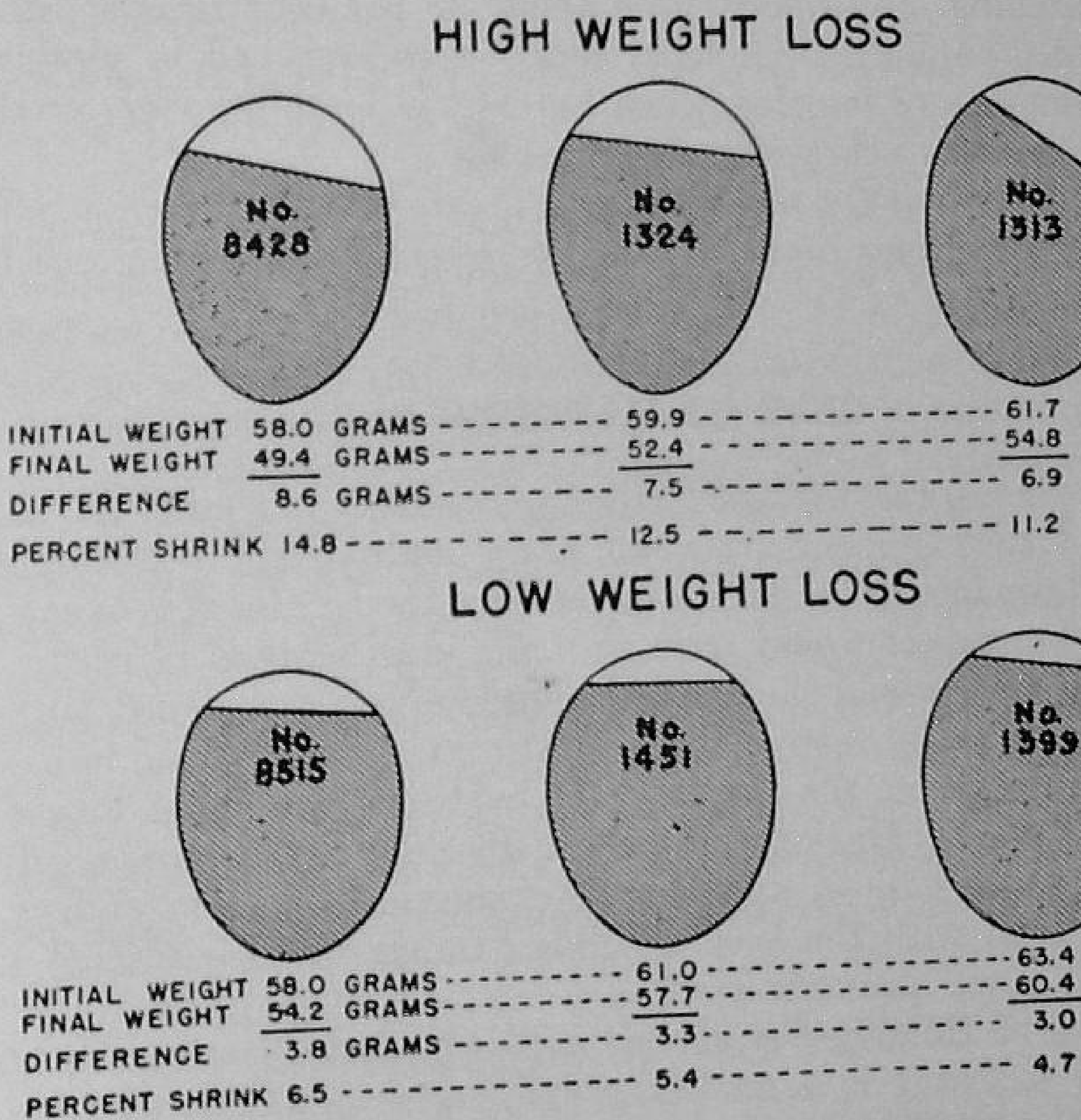


FIG. 54.—There is a wide variation among hens in weight loss of their eggs during incubation, because of hereditary differences in egg shell quality. (*After Quinn, Gordon, and Godfrey.*)

hatchability, to set them in separate machines so that they can be given slightly lower relative humidity during the incubation period. This will insure maximum hatchability of the large eggs and will bring all chicks out at about the same time.

Predetermining Fertility and Sex.—The manifest advantage of being able to ascertain, by external examination, which eggs are fertile before setting them, and which are males or females, is so great that it has led to much speculation.

The means of predetermining the fertility of eggs which has probably had the widest popular acceptance, is the specific gravity

test. The claim is made that an egg whose specific gravity is relatively great, is fertile, while one with a relatively low specific gravity is infertile. As a matter of fact differences in the specific gravity of eggs of certain hens may be observed whether the hens have been mated or not.

With reference to determining the sex of an egg without destroying it, the supposition which is given the widest credence, probably, is that the shape of the shell is an indication of the sex of the chick that will emerge if the egg is hatched. Needless to say it has long since been found that the long narrow eggs, sometimes credited with hatching only males, give about 50 per cent females, in the long run. Similarly, the short round eggs supposed to produce a preponderance of females, when hatched in large numbers produce a little above or below 50 per cent males.

The position of the air cell during incubation, for which a similar claim is sometimes made, is equally unreliable as a means of prejudging sex.

CARE OF HATCHING EGGS

At the time of laying, the fertile egg is usually in a fairly advanced stage of development from an early embryological standpoint, having been incubated within the body of the hen for approximately twenty hours. It would seem that the ideal method of caring for hatching eggs would be to allow development to proceed without being checked, by setting the eggs at once. Poultrymen, however, usually are under the necessity of holding them for a longer or shorter period. During this period development is suspended, or at least is very slow, and the very practical question of how to handle them with the least possible damage to their vitality and hatching power presents itself.

Length of Holding Period.—It is the modern view that holding eggs for hatching is a necessary evil, to be practiced as little as possible, even under the best conditions. Although there are a few records of chicks having hatched from eggs held as long as thirty-five days, all available data are in agreement in showing that hatchability decreases as the time of holding is increased. Commercial hatchery practice is to set twice a week, and many operators will not accept eggs more than one week old. Individual breeders may find it advisable to hold eggs for incubation as long as ten days if correct holding conditions are provided.

Curiously enough, the time required for incubation seems to be directly related to the age of the eggs set. Observations at the Missouri Station were that eggs which were from fourteen to twenty-one days old required from fourteen to eighteen hours longer for incubation than did eggs which were less than eight days old when set. Other studies have shown similar results.

Holding Temperature.—It is the general belief that the sooner the embryonic development under way at the time of laying is checked, the better are the chances of holding eggs successfully for hatching. This belief has led to the widespread adoption of the practice of gathering eggs frequently during the incubating season, and putting them in a cool place immediately.

Repeated tests have shown that eggs held at 50° to 55° F. hatch better than those held at 30° to 40° or at 60° to 75° F. The upper and lower limits are not specific because the time of holding is also involved, but holding for prolonged periods at either the high or the low temperatures causes many of the embryos to die during the first few days of incubation.

Position.—If eggs for incubation are to be held not more than a week, their position is not of great importance. They may be held in ordinary egg cases, preferably being packed large end up, or they may be laid in trays in the natural horizontal position.

Turning.—As already pointed out, the yolk, with the germ spot uppermost, tends to float near the shell. It is prevented from coming in actual contact with the shell membrane by the dense layer of white which surrounds it. When left in the same position for a considerable time a constant though gentle tendency upward parts the dense white and allows the germinal disc to come in contact with the shell membrane. With evaporation constantly taking place, the tiny embryo may adhere to the membrane and be destroyed. When the eggs are not allowed to remain in the same position, but are turned fairly frequently, a new point of contact is given, and more white brought between the germ and the shell membrane. Turning is of no practical importance if eggs are to be held no longer than one week. If they are to be held for a longer period, there is a distinct advantage in turning them daily.

DEVELOPMENT OF THE CHICK

It is a matter of common observation that the reproductive cycle of birds differs from that of domestic mammals in at least two particulars. First, the fertilized ovum never forms an organic connection with the mother, and second, embryonic development, for the most part, takes place outside the body of the mother.

The normal incubation period of chicken eggs is twenty-one days, though there is some variation in each direction. The eggs of Leghorns and other light breeds commonly hatch a few hours earlier than those of the heavier breeds. For a general statement it is well to remember that for each species of birds the incubation period is of definite duration; that under conditions of artificial incubation it can be lengthened somewhat with ease, but that it can be shortened only with extreme difficulty.

Shortly after incubation begins, the third germ layer, or mesoderm, originates or becomes differentiated by growing into the blastocoele between the ectoderm and the entoderm in much the same way that the entoderm earlier pushed into the blastocoele. Thus the blastoderm at this stage consists of three distinct layers of cells resting on the surface of the yolk, *i.e.*, ectoderm, mesoderm and entoderm. These three layers constitute the materials out of which the various organs and systems of the body are to be developed.

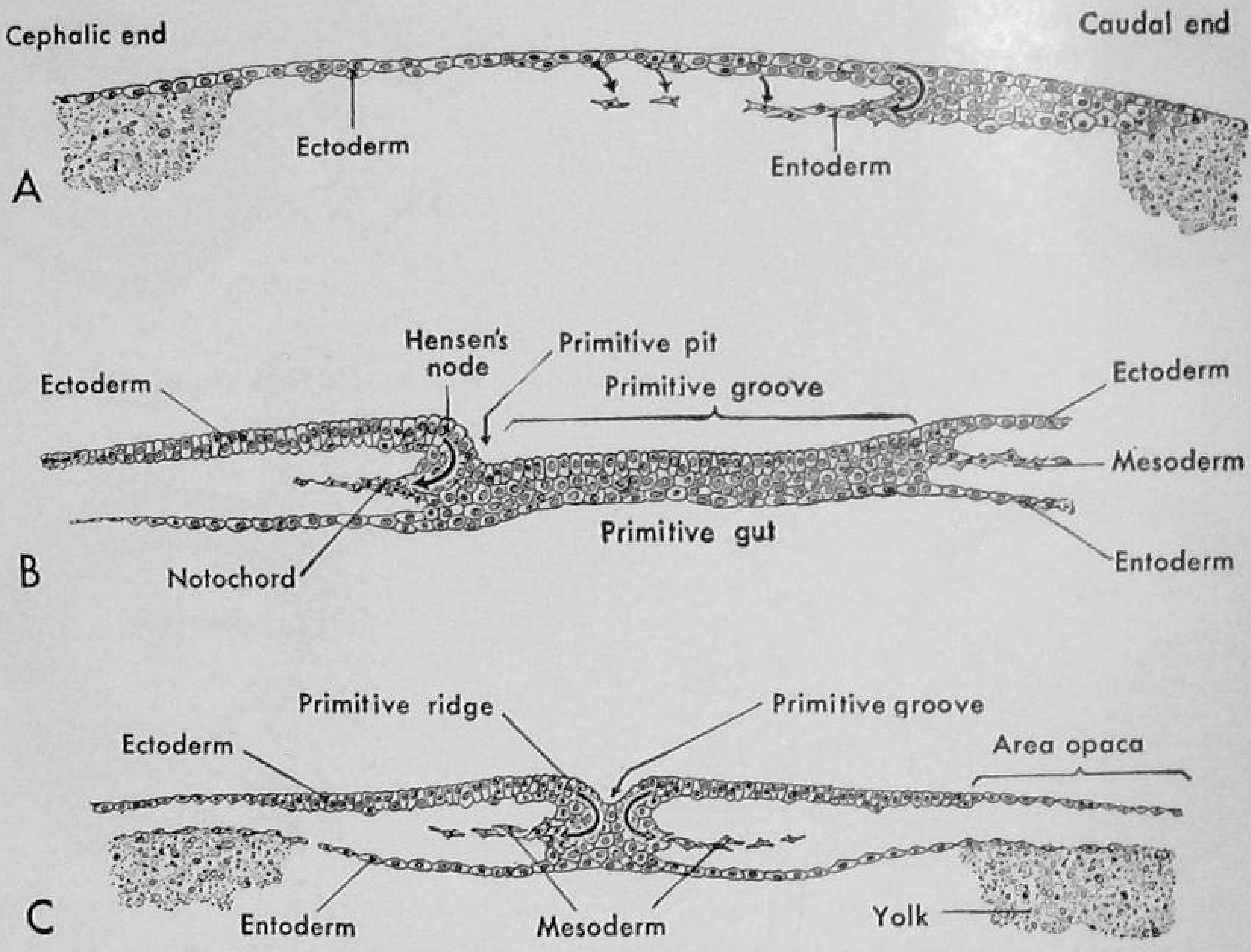


FIG. 57.—Schematic diagrams indicating the cell movements involved in the gastrulation of chick embryos. (From Patten, "Early Embryology of the Chick" 4th edition. By permission of The Blakiston Company, publishers.) (A) Longitudinal section of the blastoderm from a pre-primitive streak chick during entoderm formation. (B) Longitudinal plan of embryo of approximately 17 hours of incubation to show the relations of the various parts. (C) Cross section of an embryo in the primitive streak stage to show the turning in of cells at the primitive groove to enter the mesodermal layers.

From the ectoderm, the skin, feathers, beak, claws, nervous system, lens and retina of the eye and the linings of the mouth and vent are developed. The bones, muscles, blood, reproductive and excretory organs develop from the mesoderm, while the entoderm produces the linings of the digestive tract and the respiratory and secretory organs.

Gastrulation is usually, though by no means always, complete by the time the egg is laid. It seems to have been shown conclusively

that the period of the gastrulation process is an exceedingly critical one, while the early postgastrula stage, during which most eggs are laid, is comparatively non-critical.

The stage of embryonic development in fresh-laid fertile eggs tends to be characteristic of individual hens, and appears to be correlated with hatching power. At the Massachusetts Station, pre-gastrula and early gastrula were the most common stages of development in eggs from low-hatching hens. Early gastrula stages were characteristic of hens with medium hatching power, and well-advanced gastrula was most commonly found in eggs from hens which gave a high percentage hatch.

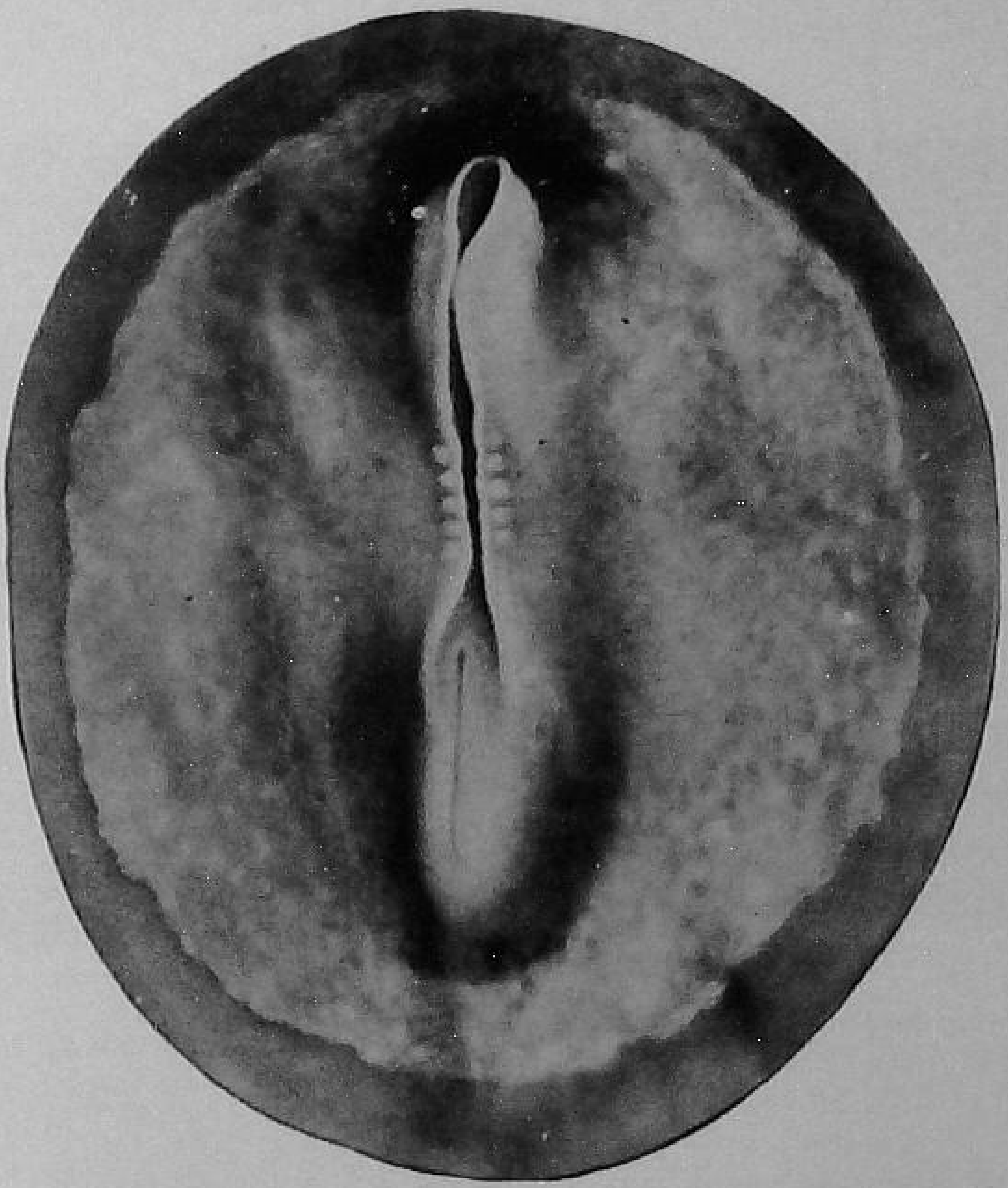


Fig. 58.—Chick embryo of 25-26 hours photographed by reflected light to show its external configuration. (From Patten, "Early Embryology of the Chick" 4th edition. By permission of The Blakiston Company, publishers.)

Too much development at the time of laying may be as detrimental as too little. Observations made by workers in the U. S. Department of Agriculture indicate that maximum hatchability occurs when the interval between successive eggs is twenty-seven hours, and that there is a marked decrease when the interval is in excess of twenty-eight hours.

If, after laying, the temperature of a fertile egg is allowed to fall below 80° F., development ceases. The egg remains quiescent

The growth of the amnion constricts the opening from the intestine to the yolk sac, thereby forming what is called the yolk stalk. It also brings the yolk stalk into close contact with the allantoic stalk. These with their blood-vessels are included in an extension of the embryonic body wall to form the umbilical cord.

Up to the sixth or seventh day there is nothing about the chick embryo which would help one to distinguish it from the embryo of other familiar animals. On the sixth day the main divisions of the legs and wings can be observed. The body, which has been very small in proportion to the head, begins to develop more rapidly. What appears to be voluntary movement may be noticed if the egg is opened.

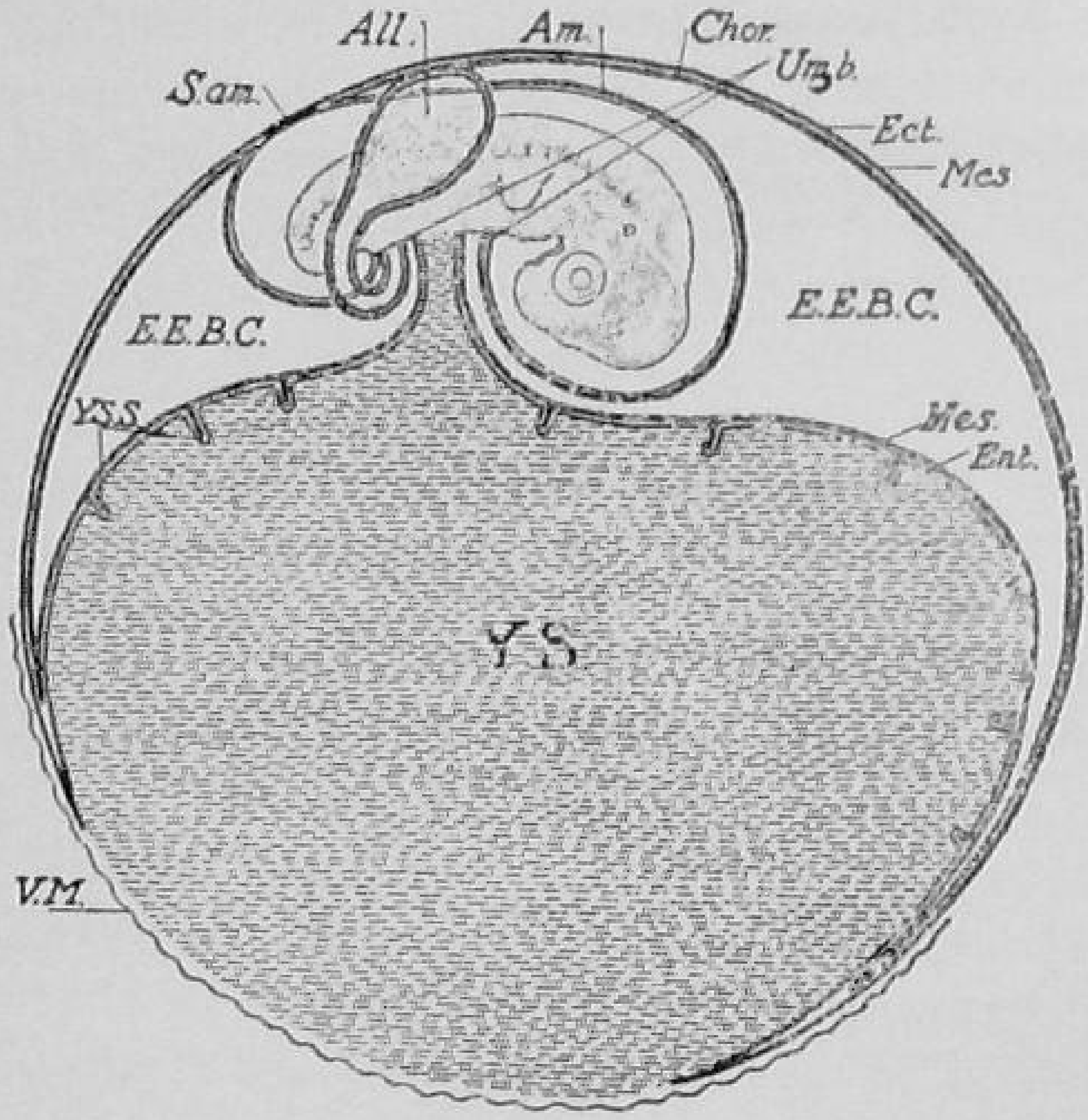


Fig. 60.—Diagram of the chick and its embryonic membranes during the fourth day of incubation. The abbreviations used in this and also in Figure 61 are as follows: *Alb.* albumen; *Alb.S.*, albumen sac; *All.*, allantois; *All.C.*, cavity of allantois; *All.I.*, inner wall of allantois; *All.S.*, stalk of allantois; *Am.*, amnion; *Am.C.*, amniotic cavity; *Chor.*, chorion; *C.T.R.*, connective tissue ring; *Ect.*, ectoderm; *E.E.B.C.*, extra-embryonic body cavity; *Ent.*, entoderm., *Mes.*, mesoderm; *S.-Am.*, sero-amniotic connection; *S.Y.S.U.*, sac of yolk sac umbilicus; *Umb.*, umbilicus; *V.M.*, vitelline membrane; *Y.S.*, yolk sac; *Y.S.S.*, yolk sac septa. (*After Lillie.*)

During the eighth day the feather germs appear in definite tracts and on the ninth the contour of the embryo becomes quite birdlike. There is a chalky deposit about the mouth opening which is the beginning of the horny beak. By this time the allantois nearly surrounds the embryo, amnion and yolk. By the thirteenth day the down is distributed over the body and its color may be seen through the thin walls of the sacs which still enclose the individual down feathers. On this day the scales and nails appear on the legs and feet. By the sixteenth day they are quite firm and horny, as is also the beak.

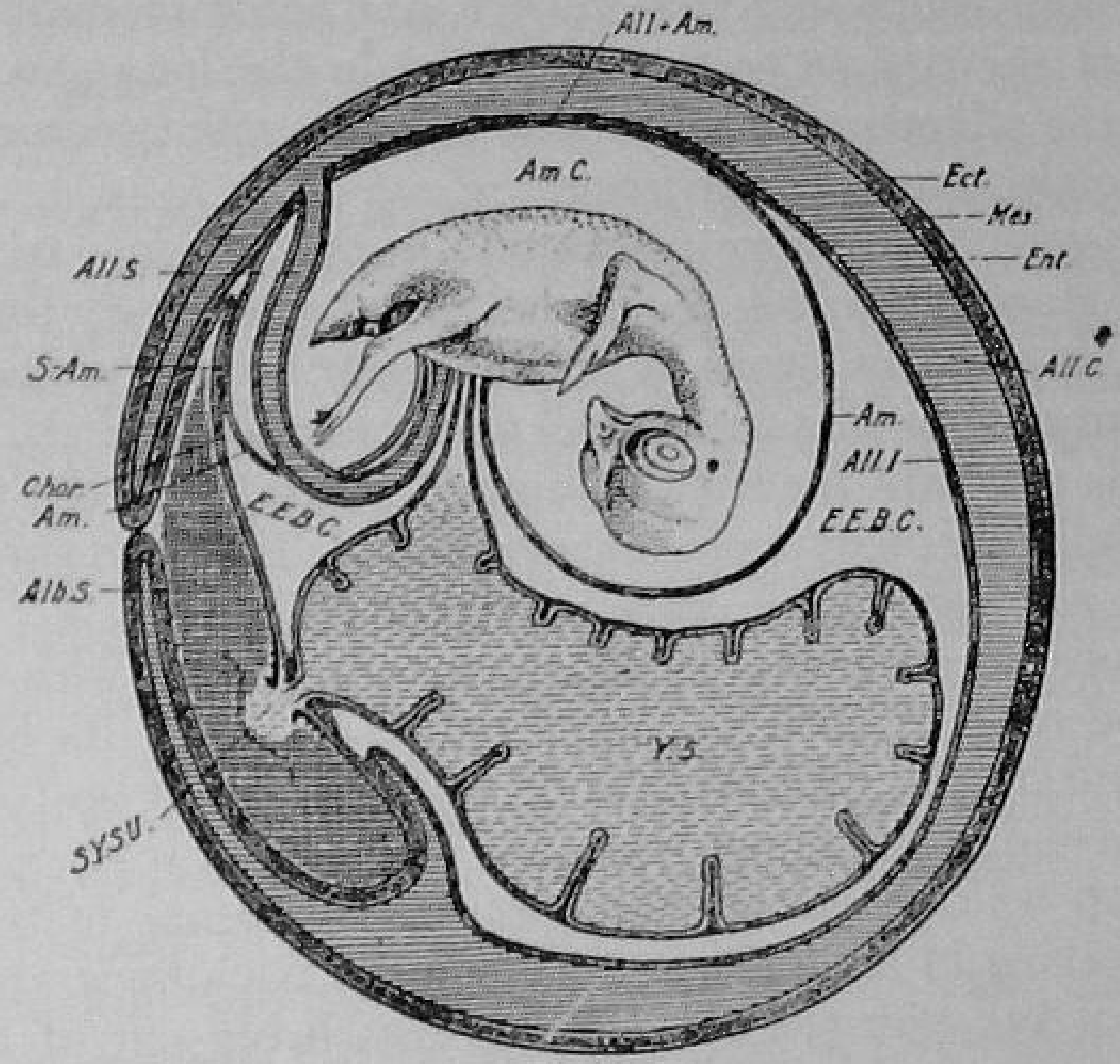


FIG. 61.—Diagram of the chick and its membranes during the twelfth day of incubation. For the designation of parts see legend of Figure 60. (*After Lillie.*)

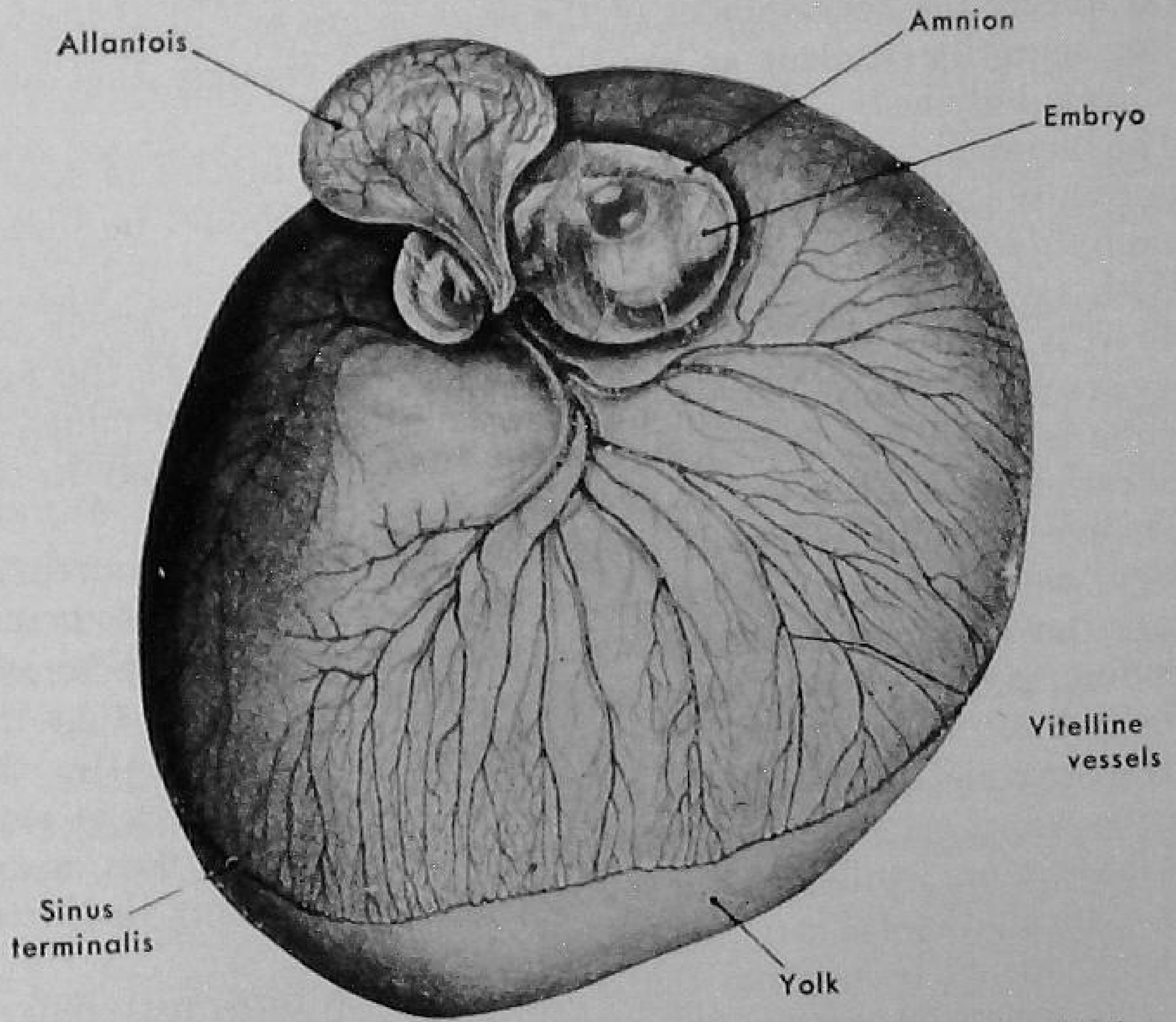


FIG. 62.—Chick of about 5½ days incubation taken out of the shell with the yolk intact. (Modified from Kerr.) The chorion and the white of the egg have been removed to expose the embryo lying within the amnion, and the allantois has been displaced upward in order to show the allantoic stalk. (From Patten, "Early Embryology of the Chick" 4th edition. By permission of The Blakiston Company, publishers.)

By the fourteenth day the embryo has accommodated itself to the form of the egg, so as to lie parallel to the long axis. By the sixteenth the albumen is nearly gone and the yolk becomes increasingly the main source of nutriment.

On the seventeenth day the amniotic fluid begins to decrease. On the nineteenth the yolk sac begins to enter the body through the umbilicus, apparently forced by the muscular tension of the amnion. The beak usually pierces the air cell and the lungs begin to function, though it is not until the shell is pipped, generally on the twentieth day, that full pulmonary respiration becomes a fact, and the allantoic circulation and respiration cease.

When fully formed, the chick is normally placed with the forepart of the body toward the large end of the egg, its head bent forward beneath the right wing and the legs brought up toward the head. The end of the upper mandible of the beak is equipped with a horny cap which bears a sharp point. By means of this, while slowly revolving in the shell, a circular path is chipped around the large end of the egg, the shell membranes being cut at the same time. When the shell is nearly cut around a final convulsion finishes the break, and the chick can emerge.

Physiological Development.—The physiological changes that occur during the development of the embryo are as full of interest to the inquiring student as are the structural changes that have just been described.

The metabolism of the developing embryo is a matter of special importance and some of the facts concerning it should be understood by the student of poultry husbandry.

With the exception of oxygen, the materials out of which the embryo is formed are all found in the various parts of the egg. They are protein, carbohydrates, fats and minerals. Of the minerals, calcium is to be noted especially because it is found largely in the shell rather than in the egg contents.

Though protein, carbohydrates and fat are all used as sources of energy, each of these serves in turn as the most important source of energy during three successive stages of development. Up to and including the fourth day it appears reasonable to believe that the carbohydrate in the egg contents is the main source. After the fourth day, and before the ninth, the production of urea is very intense, which suggests that protein is being rapidly broken down, and is therefore available as a source of energy. During the latter part of incubation fat is quite evidently the source.

It should not be inferred that any one of the three materials is the sole source of energy at a particular time. Analyses of the allantoic and amniotic fluids during development show that uric acid accumulates in the allantoic cavity beginning at some time during the fifth day of incubation, or not long after the embryonic kidney has entered into communication with the allantois. Uric

acid continues to accumulate up to the time of hatching, the period of its most intense production being from the seventh to the eleventh days. This, of course, means a continued oxidation of protein. Similarly, carbohydrate is utilized, insofar as it is available, throughout the period of incubation, although it is of special importance at the beginning. Fat, on the other hand, is not used directly until rather late in the incubation period, though the possibility of a transference of fat into carbohydrate during the early stages of development has been suggested.

Of the mineral elements involved in the metabolism of the embryo, calcium is by far the most important, if for no other reason than that for about one hundred years it was a subject of keen controversy, particularly with respect to whether calcium is actually transferred from the shell to the embryo. Concerning the essential facts there is now no important difference of opinion. They may be stated briefly as follows:

The calcium content of the inside of the egg, including the embryo, rises markedly during incubation, the rise beginning about the twelfth day.

The calcium content of the embryo increases in a parallel fashion, *i. e.*, at the same rate and during the same time, but remains always quantitatively below that of the whole egg.

The calcium content of the yolk rises slightly during the incubation period.

The calcium content of the shell membranes increases from the beginning of incubation, and rises very sharply from about the seventh day to the time of hatching.

Infertile eggs, when incubated along with fertile ones, never contain any more calcium than do unincubated eggs.

These results can be explained only on the basis of a distinct transfer of calcium from the shell to the embryo. It is further evident that the transfer is due to the presence of the embryo, for infertile eggs are not affected. Of particular interest is the fact that the embryo seems to draw on the shell exclusively for its supply of calcium without making use of what is in the yolk until after hatching.

Critical Periods.—Embryo mortality is not uniformly distributed over the twenty-one days of incubation. Instead, there are definite peaks in the mortality curve. About half of the total mortality normally occurs during the last three or four days, with the nineteenth day representing the maximum. Another significant peak, though it is quantitatively less important, is during the second, third, and fourth days. A third, though usually lower, peak occurs between the tenth and fourteenth days.

Temperatures of Eggs under Natural Incubation.—The temperature at which eggs are naturally incubated depends primarily upon the temperature of the hen. This is quite variable, both among hens on the same day and for the same hen from day to day, though the variation appears to be much less among broody hens than among non-broodies.

There is a popular supposition that the temperature of a broody hen is relatively high, and that one of the characteristics of broodiness is the so-called "broody fever." The facts are that the temperatures reported for broody hens average about 2° F. below those for non-broody hens, being comparable to the temperatures of non-broody hens at times of minimum activity.

Observations made at the Montana Station showed that the temperature at the top of eggs containing live embryos remained fairly constant, averaging 102.3° F. The temperature at the bottom of the egg, however, increased several degrees as incubation progressed. During the first few days it was from 15° to 18° lower than the temperature at the top of the egg, but during the last few days it was only 10° or 12° lower.

Temperatures of Eggs during Artificial Incubation.—Just how to apply these findings to the problem of artificial incubation is none too clear when the several different types of incubators are taken into account. Presumably there is an optimum temperature condition for each type of incubator, and occasionally for an individual machine. Not only this, but optimum temperature must always be a relative matter in that it is partially dependent upon humidity and air movement, as well as upon the exact location of the thermometer.

With the advent of mammoth incubators of the forced-draft type it soon became apparent that actual optimum incubating temperatures were lower than had commonly been supposed. Instead of 102° to 103° F., as measured by a thermometer with its bulb at the same level as the top of the eggs, either under the hen or in a still-air machine, the actual egg temperature was about 100° F. or a little less.

Extensive tests at the National Agricultural Research Center, Beltsville, Maryland, have shown an optimum incubation temperature of 100° F. when the relative humidity was kept at 60 per cent, the concentration of oxygen at 21 per cent, the carbon dioxide below 0.5 per cent, and the air movement past the eggs approximately 12 cm. (5 inches) per minute. In these tests the percentage hatch decreased at temperatures above and below 100° F., until at 96° and at 103.5° F. nearly all the embryos died.

Effects of High Temperature.—It is a well-known fact that the range above that considered normal, is much more limited than the range below. This is not altogether surprising perhaps, since in

natural incubation the opportunities for overheating appear to be very much less than for underheating.

Three principal effects of high temperatures are (1) marked speeding up in the rate of development, with an accompanying increase in carbon dioxide output; (2) the production of abnormal embryos in the early stages; and (3) the lowering of the per cent of fertile eggs which hatch.

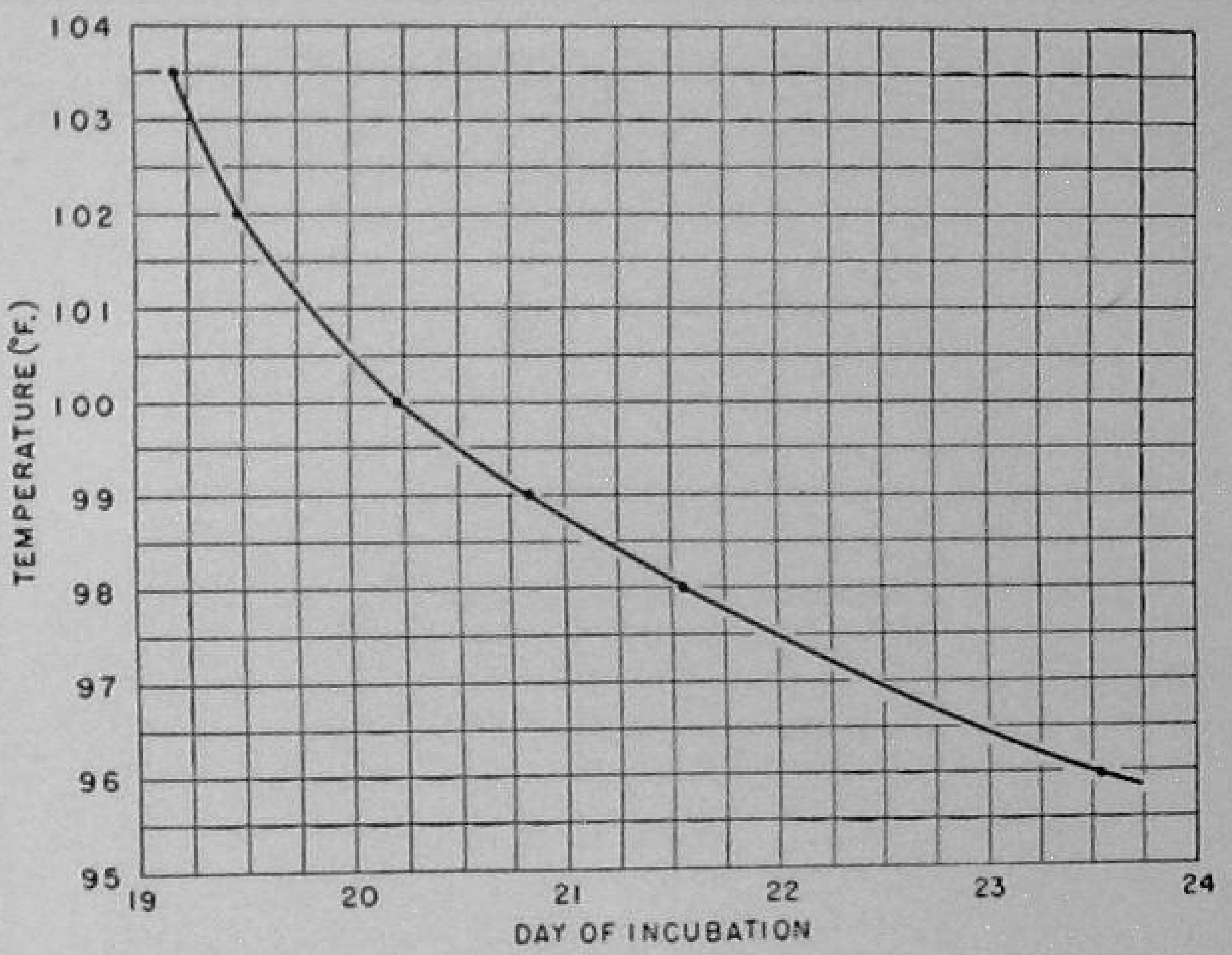


FIG. 63.—Effect of temperature on total incubation time. As the incubation temperature is decreased from 103.5° to 96° F., the number of days from the beginning of incubation to hatching increases from slightly more than 19 to 23½. (*Courtesy of U. S. Department of Agriculture.*)

The speeding up of development as the result of abnormally high temperatures with an accompanying increase in CO_2 output has been observed by a number of workers. During the greater part of the incubation period the developing chick reacts to increases in temperature as a cold-blooded animal, by increasing the discharge of CO_2. From about the nineteenth day until hatching it is neutral in this respect, and raising the external temperature does not seem to affect the CO_2 production. The day after hatching the chick responds to rises in external temperature as a warm-blooded animal, by decreasing the output of CO_2.

The effect of temperature on the length of the incubation period is shown in Figure 63.

High lethal internal egg temperatures have been determined as ranging from 106° to 110° F. during the first five days of incubation, and from 114° to 118° thereafter.

An accompaniment of high, though not necessarily lethal temperatures, is the production of abnormalities of various sorts, including

Success in the hatchery business depends upon the correct application of the principles and practices of incubation, and also upon the proper organization and operation of the enterprise.

Location.—Unless the hatcheryman is also a poultry breeder and sells no chicks other than those hatched from his own flocks, he must locate his plant in a territory where the necessary eggs are being produced and can be purchased.

Some hatcheries sell most of their chicks by mail and, since orders may come from all directions, they should be located somewhere near the geographic center of the poultry producing area. In recent years the trend has been definitely toward local or community hatcheries, and the best location for these is clearly in a community where there is likely to be a good demand for chicks within a radius of 30 to 50 miles. Location in a natural trading center is distinctly advantageous, and the specific location should be such that customers can find it easily and can reach it without difficulty.

The Hatchery Plant.—The hatchery building should be attractive in appearance, should be kept clean and sanitary, and should be so arranged as to make it convenient for chick customers as well as for flock owners who deliver eggs. Chick customers are often gained or lost through the appearance of the hatchery plant.

A large hatchery will have an office, an egg-receiving room, a supply room, and a shipping room, as well as a display and salesroom, and the incubator room or rooms. If started chicks are sold, it will be necessary to have a room for the battery brooders, and if the hatcheryman is also a feed dealer it may be desirable to have a feed room in addition to the customary display and salesroom. In small hatcheries many of these are combined.

The Egg Supply.—Most hatchery operators have contracts or agreements with flock owners from whom they get their hatching eggs, and success in the business is closely related to the degree of cooperation and confidence which can be established between the hatcheryman and his flock owners. The number of flock owners will depend on the size of the hatchery and the size of the flocks, but it is necessary to obtain eggs from 100 to 125 breeding females for each 1000 egg capacity. If the flocks average 250 hens each, this will mean 16 to 20 flocks for a hatchery of 40,000 egg capacity.

Quality of hatching eggs is of paramount importance to the hatchery operator. Unless a high percentage hatch can be obtained, profits are certain to be small. Eggs from poor quality breeding stock will result in chicks which cannot give satisfaction to the purchaser. And since there is no way of improving either the hatching power or the genetic quality of the eggs after they are received at the hatchery, the operator must of necessity be interested in the breeding and improvement practices followed by the owners of the flocks from which he obtains eggs.

The hatchery operator will usually want to specify certain minimum requirements and standard practices, and in consideration of their being faithfully met by the flock owner he will expect to pay a premium over market price for the eggs delivered. An extra premium is sometimes paid in proportion to the percentage hatch secured.

Surplus Chicks.—In the early years of the hatchery business the demand for chicks so far exceeded the available supply that purchasers had to place their orders several weeks in advance in order to get chicks at a specified time. As more and more hatcheries came into existence this condition gradually changed, and the practice of placing orders in advance of delivery largely disappeared in many sections of the country. With no exact knowledge of how many chicks can be sold, the hatcheryman can easily find himself with a large surplus of chicks in certain weeks. Sound business procedure would certainly indicate the advisability of limiting the number of eggs set to not more than 10 per cent in excess of the quantity necessary to produce sufficient chicks to fill orders on hand at the time of setting.

Efforts of certain hatcherymen to dispose of surplus chicks resulted in many practices which were distinctly detrimental to the industry. The effect of these practices eventually led to the establishment by the Federal Trade Commission of a series of fair-trade practice rules for the baby-chick industry.

Shipping Chicks.—Day-old chicks are usually priced to include delivery to the purchaser. They may be shipped by parcel post or express, or may be delivered in the hatcheryman's own trucks. In any case, they are expected to reach their destination within seventy-two hours after hatching.

The standard container for baby chicks is a corrugated paper box measuring 18 by 24 by 6 inches inside, and divided into four compartments which hold 25 chicks each. Smaller boxes to accommodate 25 to 50 chicks each are also used when necessary.

Started Chicks.—Since much of the mortality in young chicks often occurs during the first two or three weeks, many purchasers prefer to pay an extra price for chicks which have been brooded through this initial period. Hatcherymen who have offered this service have been divided in their opinions regarding its place in the business. Every sale of started chicks obviously means one less sale of day-old chicks. It also means more expense to the hatcheryman and he must price the started chicks to cover the extra cost. For reasons of sanitation and disease prevention it is essential that the started chicks be brooded in a room or building which is entirely separate from the hatching and sales rooms. As with many other practices, the selling of started chicks will doubtless persist in certain sections or communities and largely disappear in others.

CHAPTER 6

BROODING AND REARING

Brooding and rearing deal with the growth of the chick after hatching, and more specifically with those factors affecting growth that are more or less completely under the control of the poultryman. The growth attained by an individual will depend upon its inherited ability to grow, its food supply, and such environmental factors as temperature, air supply and protection from parasites and enemies. Reference has already been made to the marked influence of heredity. Nutrient requirements and their importance are given special consideration in a later chapter.

Aside from their nutritional needs, there is little basic information concerning the requirements of chicks during the brooding period. Yet in many ways this is the most critical and difficult period in the management of domestic birds. No poultry business can long succeed without a practical and efficient chick-rearing department. Chickens must be well grown before they can yield a monetary return to their owner, regardless of the nature of the particular poultry product he is selling. Furthermore, a lack of the knowledge and ability to rear chicks is one of the most common causes of low profits and of failure in poultry keeping.

The brooders available, and the brooding practices recognized as essentially sound, are the result of empirical methods of investigation. They are not based on a definite knowledge of the oxygen requirements, the carbon dioxide production and toleration of chicks of successive ages, or of the relation of relative humidity to the foregoing, and to temperature.

Successful brooding is still largely an art, though information is gradually being accumulated which may eventually put artificial brooding on a scientific basis.

BROODING REQUIREMENTS

The requirements of brooding appear to be essentially those of housing, with the addition of temperature regulation. A complete brooder is simply a special form of house designed for the purpose of keeping chicks comfortable. To be commercially practical, brooding equipment must also be reasonably low in cost.

Temperature.—There is no general agreement among poultrymen as to what constitutes exactly the proper hover temperature for

chicks just out of the incubator or at succeeding ages. There is no cumulative experimental evidence determining definitely what these temperatures should be.

Ideal temperature conditions probably exist when there is a range in temperature always available to the chicks, from a maximum of not less than 100° F. to a minimum of 60° or 70° F. When they have opportunity for a choice, chicks soon learn to find the temperature that is most comfortable to them. Trouble comes not so much from temporary exposure to low or to variable temperatures, as from continuous exposure to temperatures that are too high or too low, with no opportunity for the chicks to move at will to more comfortable temperatures.

FIG. 69.—A range of this sort is very nearly ideal for rearing chickens by the colony system. (*Photo by U. S. Department of Agriculture.*)

Careful tests have shown that, with the temperature taken $2\frac{1}{2}$ inches above the litter, chicks are apparently comfortable at all temperatures in the range from 80° to 110° F. Not until the air temperature is some five degrees above or below this range is there definite indication of discomfort and of a tendency to avoid such areas. On the other hand, extensive tests at the Beltsville Agricultural Research Center involving 72 experiments with 30 chicks each, showed a maximum growth response during the first nine days after hatching when the average temperature was 91° F., dropping from 94° on the first day to 88° on the ninth. In a later series of 53 similar experiments, best results were obtained when the temperature was reduced uniformly from 94° on the first day to 80° on the eighteenth. Variation in controlled relative humidity from 35 per cent to 75 per cent made no appreciable difference in growth to 18 days of age.

It is unsafe to lay down absolute rules for all breeds and conditions. First and always the chicks must be comfortable. In quite cold weather it is likely to take a higher temperature to accomplish this than in more moderate weather. Less heat is required for snappy, vigorous stock than for birds of less vitality. The temperature should in all cases be reduced as the chicks grow older, as rapidly as is compatible with their comfort, and artificial heat taken away altogether as soon as they are well feathered out.

While it is exceedingly desirable to get the chicks on a self-sustaining basis with regard to the maintenance of body temperature, it is always better to err on the side of too much heat than too little. This is particularly true in cold weather, when a high hover temperature is necessary to warm chicks up quickly when they get cold. It does not hurt chicks to run out in quite cold weather, provided they can get warm quickly whenever they desire. Even after all artificial heat has been done away with, and the chicks well feathered, the brooding apparatus should be held in readiness against unusually cool nights, which are likely to produce crowding if a little heat is not supplied.

An experienced poultryman depends almost entirely upon the action of the chicks in regulating the brooding temperature, but a beginner will find a thermometer helpful.

The thermometers used should be carefully tested at the beginning of each season, if they are to be relied upon, just as in the case of incubator thermometers.

Effects of Chilling.—A little chick, compelled to remain in the cold after he begins to feel chilly, soon becomes helpless. This is apparently caused by the paralysis of the breathing apparatus. The lungs are located on either side of the median line of the back at the circumference of the body cavity. Lobes of the lungs extend between the ribs and are protected from the outside temperature only by a thin membrane, the skin, and a coat of down. It is not surprising that when the chick is chilled the lungs are quickly affected.

In natural brooding, the back and lungs are the best protected portions of the body. When a chick becomes uncomfortably cold under conditions of artificial brooding, and is unable to locate heat enough to warm him quickly, he seems to obey that instinct which tells him to get his back up against the mother hen. The result is that he tries to crawl under the other chicks. This, taken up by the other chicks in turn, results in bunching and crowding with the accompanying evils of smothered chicks and a diminution of thrift on the part of the entire flock.

Diarrhea can be produced experimentally in baby chicks by exposing them to moderate changes in temperature. A sudden increase in temperature is just as detrimental as a decrease. Chicks kept under observation for a period of ten weeks showed that though the exposure to a change in temperature was not always fatal, there

was a serious disturbance in metabolism which resulted in abnormal development.

Parker, at the California Station, studied the effect of early handicaps, including poisons, starvation, and high and low temperatures, on the rate of yolk absorption of chicks, and on their subsequent weight at twenty weeks of age. Little effect was found on the course of yolk absorption. Several of the handicaps imposed had a more marked and more lasting effect on male chicks than on female chicks, when measured in terms of body weight.

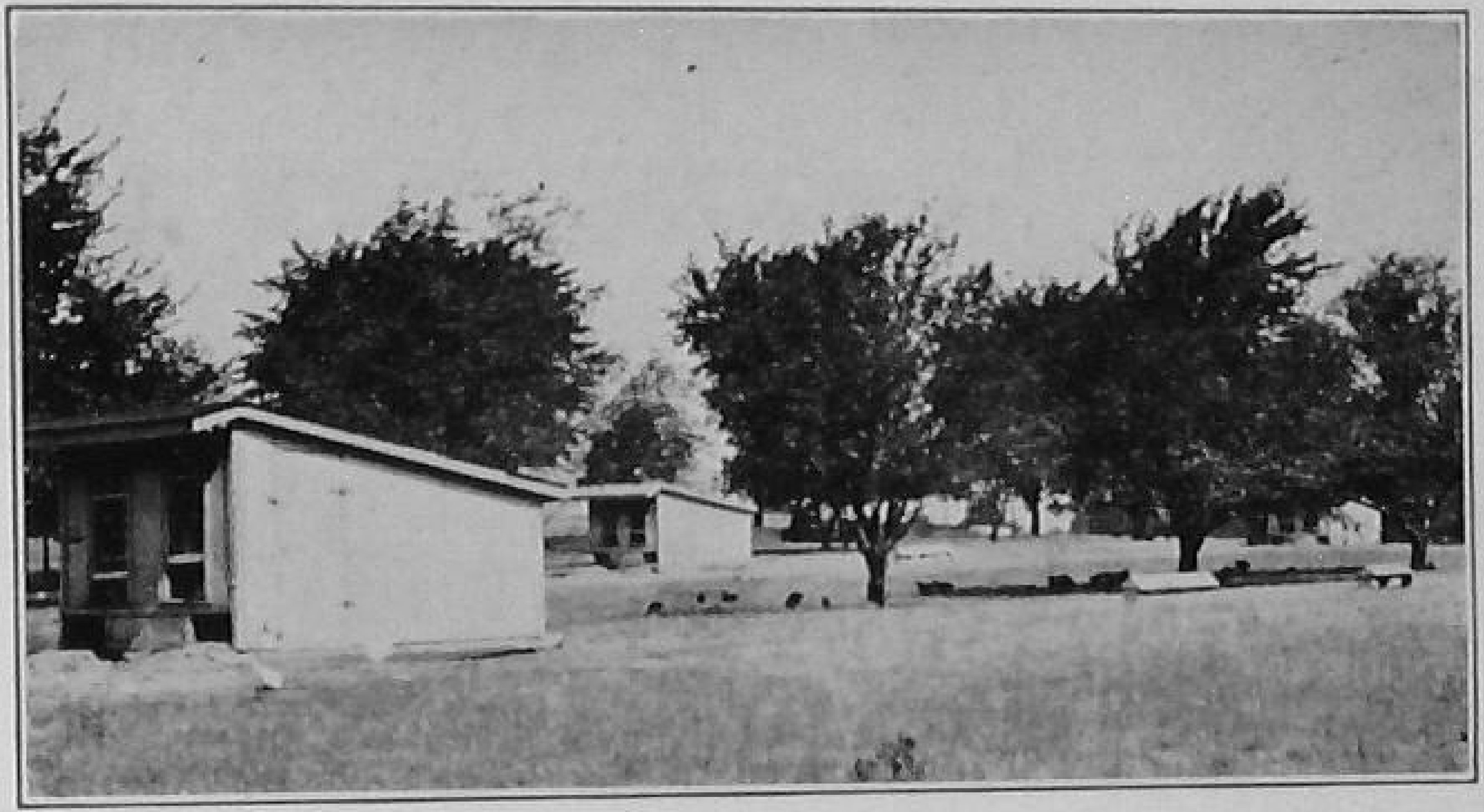


FIG. 70.—An orchard makes a fine place in which to grow chickens, provided the trees are not too close together and are trimmed high enough so that the sun's rays can strike the ground beneath them.

The low lethal internal body temperature has been studied by several workers, and ranges from 62° F. on the day of hatch to about 67° at two weeks of age, with a gradual increase to about 73° at maturity. Maryland workers found that 2-day-old chicks could stand 35 minutes exposure at −10° F., and that at twenty days of age they could stand 75 minutes before half of them succumbed.

Effects of Overheating.—Overheating occurs comparatively seldom, because chicks instinctively move away from the source of heat when too warm. If confined under a hover when the temperature runs up, they die rather quickly.

The high lethal body temperature for the chick is the same as that for older fowls, 117° F. This body temperature is reached in about ten minutes when chicks are exposed to an air temperature of 160° F. At room temperatures of 100° F., death losses among day-old chicks in sealed summer-size fibre-board chick boxes were found by Wilson at the California Station to range from 20 to 50 per cent. New Hampshire chicks were more susceptible to overheating than were White Leghorns.

Fresh Air.—When hovers are used, they must be so arranged that there will be a constantly changing supply of fresh air. With coal-stove brooders in which the hover acts largely as a deflector, there is usually good circulation of air. If a fringe or curtain is used, it should be short enough to clear the surface of the litter by at least two inches so as to permit free air movement.

With electric brooders having the heating element under the hover, particular care should be taken to see that there is a good flow of air. Not infrequently it will be discovered that even with open ventilators which appear ample, hardly any change of air is taking place. The inevitable result of such a condition is dampness.

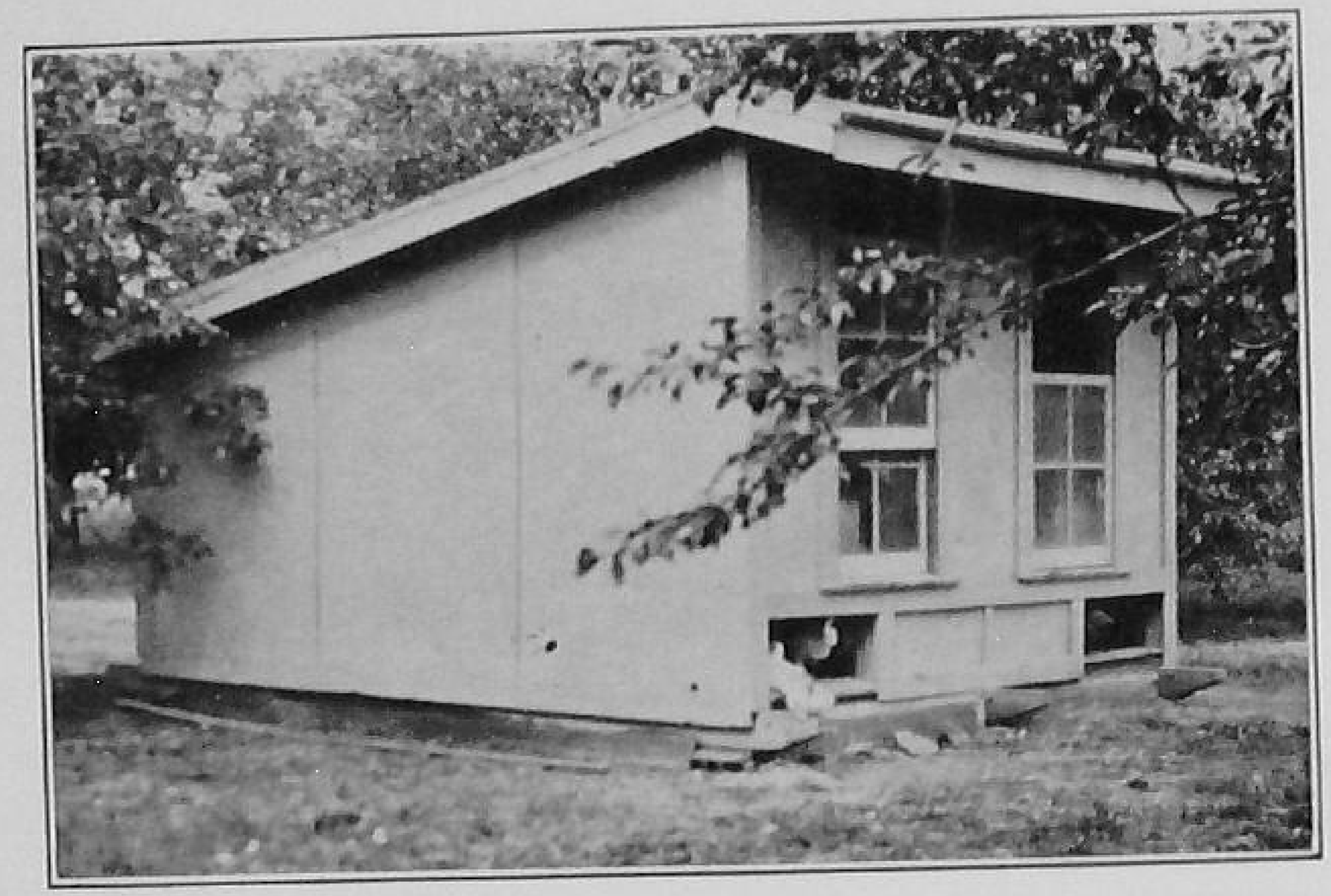


FIG. 71.—A convenient and practical type of portable colony brooder house, 10 by 12 feet in size.

Most electric brooders are now made with small circulating fans to help keep the hover area dry.

Dougherty and Moses at the California Station studied the relation of ventilation in electric brooders to the health and growth of chicks, and concluded that the development of dampness precedes serious vitiation of the air by a considerable margin. They found that a rate of circulation of air through the hover of 1 cu. ft. of air per 100 chicks per minute was insufficient to prevent excessive condensation or to meet the needs of the chicks to six weeks of age.

A flow of 2 cu. ft. of air per 100 chicks per minute was found to meet the needs fully as well as larger amounts, but it would not keep the hover dry after the chicks were three weeks old. As much as 4 cu. ft. of air per 100 chicks per minute (equal to an entire air change every 1.125 minutes in the brooders used) would not keep the hover entirely dry.

FIG. 72.—A type of prefabricated brooder house which can be purchased in sections ready to set up. *(Courtesy of The National Ideal Company.)*

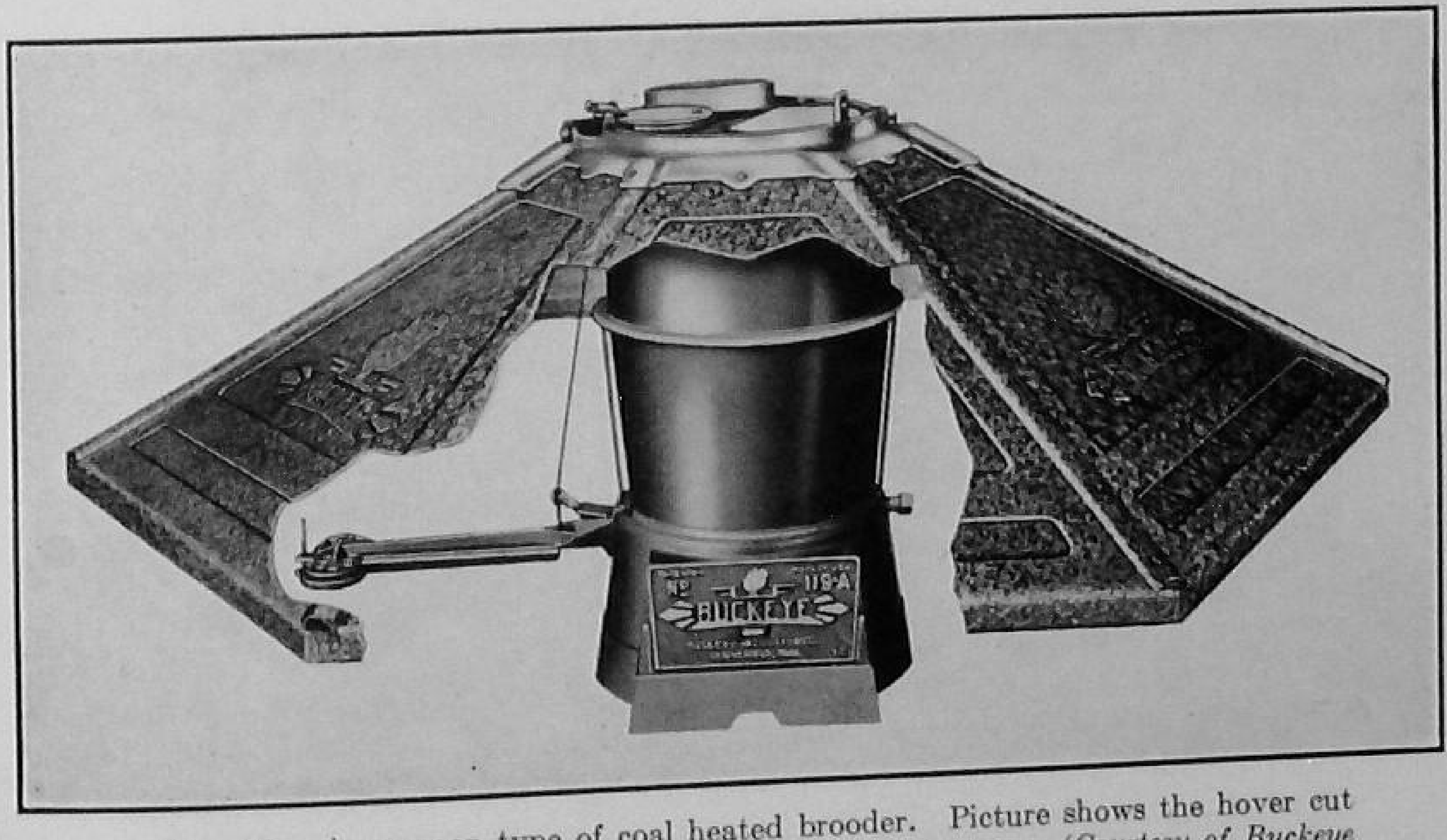


FIG. 73.—A common type of coal heated brooder. Picture shows the hover cut away to expose the thermostatic control and lower damper. *(Courtesy of Buckeye Incubator Company.)*

Such regulation of the ventilation of an electric brooder as will keep the interior reasonably dry will assure the chicks an ample supply of fresh air. Ventilation in excess of that needed to keep the hover reasonably dry and free from bad odors will not benefit the chicks, will cause an undue dissipation of heat, and will unnecessarily increase the electricity consumed.

The Washington Experiment Station recommends placing the electric brooder on a frame covered with ½-inch mesh hardware cloth, raised 2 to 4 inches from the floor, as a means of solving the ventilation problem. This permits constant air circulation and keeps the floor of the brooder clean, dry and sanitary.

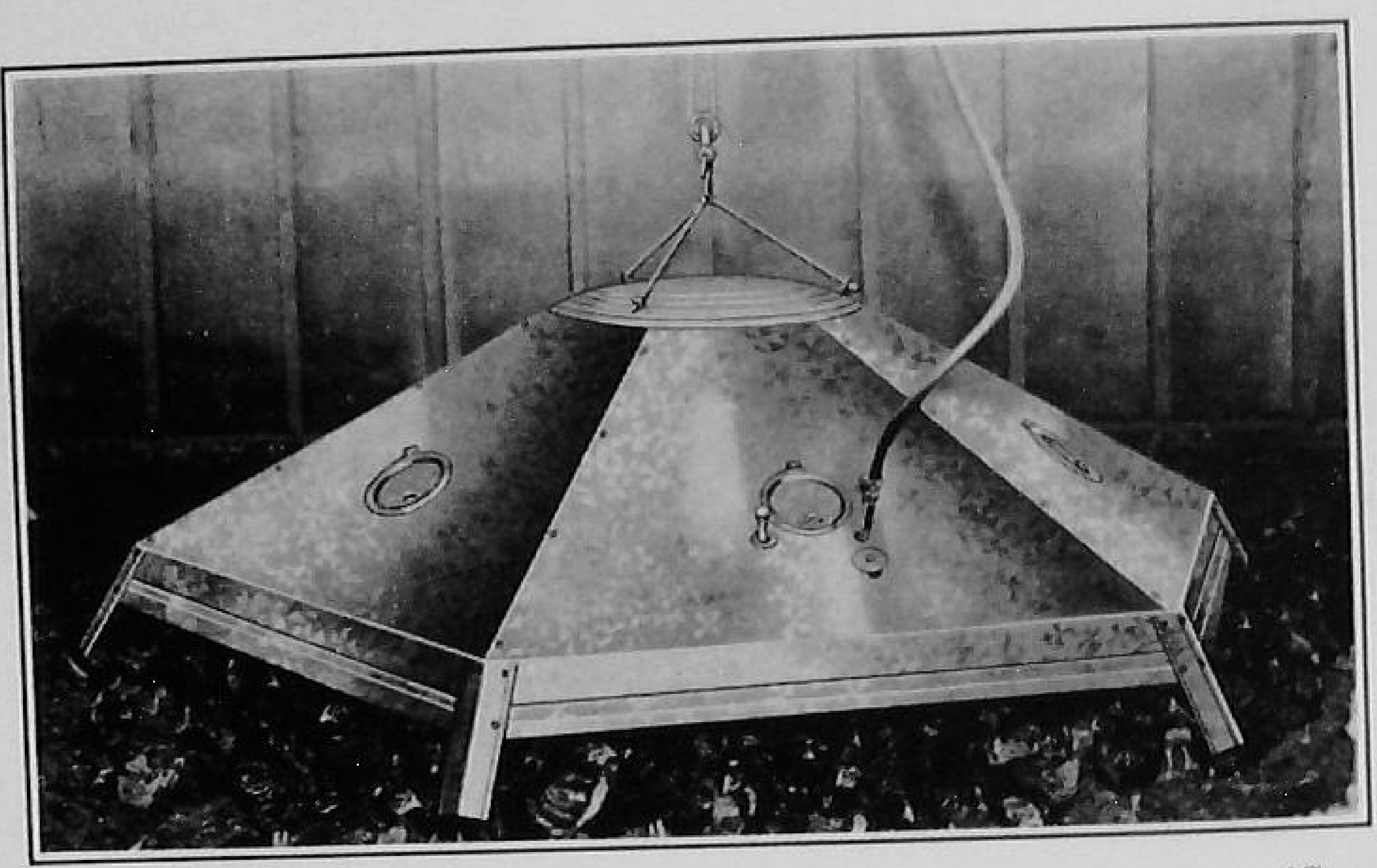


FIG. 74.—Gas heated brooders are popular in some parts of the country. (*Courtesy of H. D. Hudson Company.*)

Gas brooders are commonly installed without being vented to the outside. This often aggravates the moisture and ventilation problem because of moisture formed and condensed during gas combustion.

Hover and Floor Space.—Commercial brooders are often overrated as to their capacity. In some brooders nearly one-half the floor space under the hover is occupied by the heater.

Well-fed chicks grow rapidly, often doubling their weight four successive times in the first six weeks, and it is apparent that a brooder which is filled to capacity with day-old chicks will be badly overcrowded within a very short time.

Floor area requirements vary with the size, and therefore with the age of the chickens. As with many other management factors on which poultrymen have to make decisions, the optimum floor area for greatest biological efficiency may not be the same as the optimum for greatest economic efficiency. It is considered sound practice

to provide $\frac{1}{2}$ square foot of total brooder area per chick at the start. From 15 to 20 per cent of the total area will be hover space if hovers are used. If optimum growing conditions are to be provided, the floor area per chick must be increased by about $\frac{1}{2}$ square foot at four weeks, and again at 8, 12 and 16 weeks so that after 16 weeks there will be not less than $2\frac{1}{2}$ square feet of floor area for each chicken.

Just how many chicks to brood in one flock is a matter that must always be finally decided by the poultryman in each individual case. Large flocks effect a considerable saving in labor and avoid some duplication of equipment. On the other hand, optimum results with respect to rapid growth and low mortality can be obtained only when the number of chicks in a single flock is limited. The beginner will do well to put not more than 200 chicks under a single hover. Many experienced poultrymen, after trying the plan of brooding in flocks of 500 to 1000, have returned to the practice of putting not more than 200 to 250 chicks under one brooder, especially if the chickens are to be raised to maturity. Commercial broiler growers, on the other hand, very commonly start 600 to 1000 chicks to each brooder stove.

Ease of Disinfection.—The mutual arrangements of the brooder and the room in which it is housed, must be such that every crack and crevice may be easily reached and thoroughly soaked by disinfectant from a spray pump.

Safety from Fire.—While the brooder of today is much safer from fire than its forerunners, this point should be carefully considered in making a purchase and kept constantly in mind after the purchase. There is always a considerable fire hazard where colony brooders are being operated.

BROODING EQUIPMENT

A complete discussion of the many sorts and kinds of brooders that have from time to time been used in the commercial rearing of chicks might well be of interest, but it would be out of place in this book. Instead, there are included illustrations of many of the common types that are in use today, with some comment on the conditions to which they are best adapted and some of the limitations which must be kept in mind.

Portable brooders with individual heating units are made in many styles and sizes. They may be heated by coal, oil, gas or electricity. They vary in size from small lamp-heated or electric brooders of 50-chick capacity to large coal burners producing sufficient heat to warm a room for 1500 to 2000 chicks.

Battery brooders are a special type designed to accommodate large numbers of chicks in a limited space for short periods of time. They are most useful in carrying chicks from hatching time to about four weeks of age, and are never entirely satisfactory for raising

chickens to maturity. They are very helpful as a means of avoiding most of the accidental mortality that is often experienced during the early weeks of colony brooding.

To the poultryman who is mechanically minded, the construction of home-made equipment is always a challenge, and brooding equipment has offered many opportunities for the display of all the skill and ingenuity of which such an individual is capable. Hot-water systems, battery brooders, heated-floor brooders, wood-burning brooders, and others have been built at home and used successfully.

Commercial broiler growers use all of the foregoing plus a variety of systems which depend upon the circulation of hot air or hot water from a central heating plant.

FIG. 75.—A drum-type oil-burning brooder. When temperature conditions are right the chicks distribute themselves over the "comfort zone" when settling down for the night. (*Courtesy of The Simplex Brooder Stove Company.*)

In a series of Delaware tests in which more than 35,000 broilers were used, gas-heated brooders gave production results equal to individual coal-heated brooders, but at a 27 per cent greater fuel cost. Oil-burning brooders took less labor than coal stoves. A central hot air system equalled individual coal stoves in production results and saved a great deal of labor. Infrared bulbs were much more costly as a source of heat than were the other types of brooders. The final rating was (1) central hot air; (2) oil; (3) individual coal stoves; (4) gas, and (5) infrared bulbs.

As suggested by the data in Table 17, based on a survey of 20,000 farms by the U. S. Department of Agriculture, the source of heat used is determined partly by climate, and partly by what is conveniently and economically available.

TABLE 17.—PERCENTAGE OF ALL CHICKENS RAISED, 1949, THAT WERE BROODED WITH HEAT FROM EACH OF SEVERAL SOURCES. *(From a Survey of 20,000 Farms by the U. S. Department of Agriculture.)*

Section	*Source of heat*					
	Electricity	*Oil*	*Coal*	*Gas*	*Wood*	*Hens*
Northeast (New England, N. Y., N. J., Pa., Del., Md.)	22	10	57	8	2	1
Corn Belt (Ohio, Ind., Ill., Iowa, Mo.)	44	31	9	6	4	6
Lake States and Great Plains (Mich., Wis., Minn., N. D., S. D., Nebr., Kans.)	32	48	5	6	1	8
Appalachian (W. Va., Ky., Tenn., Va., N. C.)	22	18	20	4	21	15
Southeast (S. C., Ga., Fla., Ala.)	19	41	16	10	6	8
South (Miss., La., Ark., Okla., Texas)	18	32	2	29	6	13
Mountain (Mont., Ida., Wyo., Colo., N. Mex., Ariz., Utah, Nev.)	36	37	8	5	1	13
Pacific (Wash., Oreg., Calif.)	61	22	3	11	1	2
United States	29	27	21	10	6	7

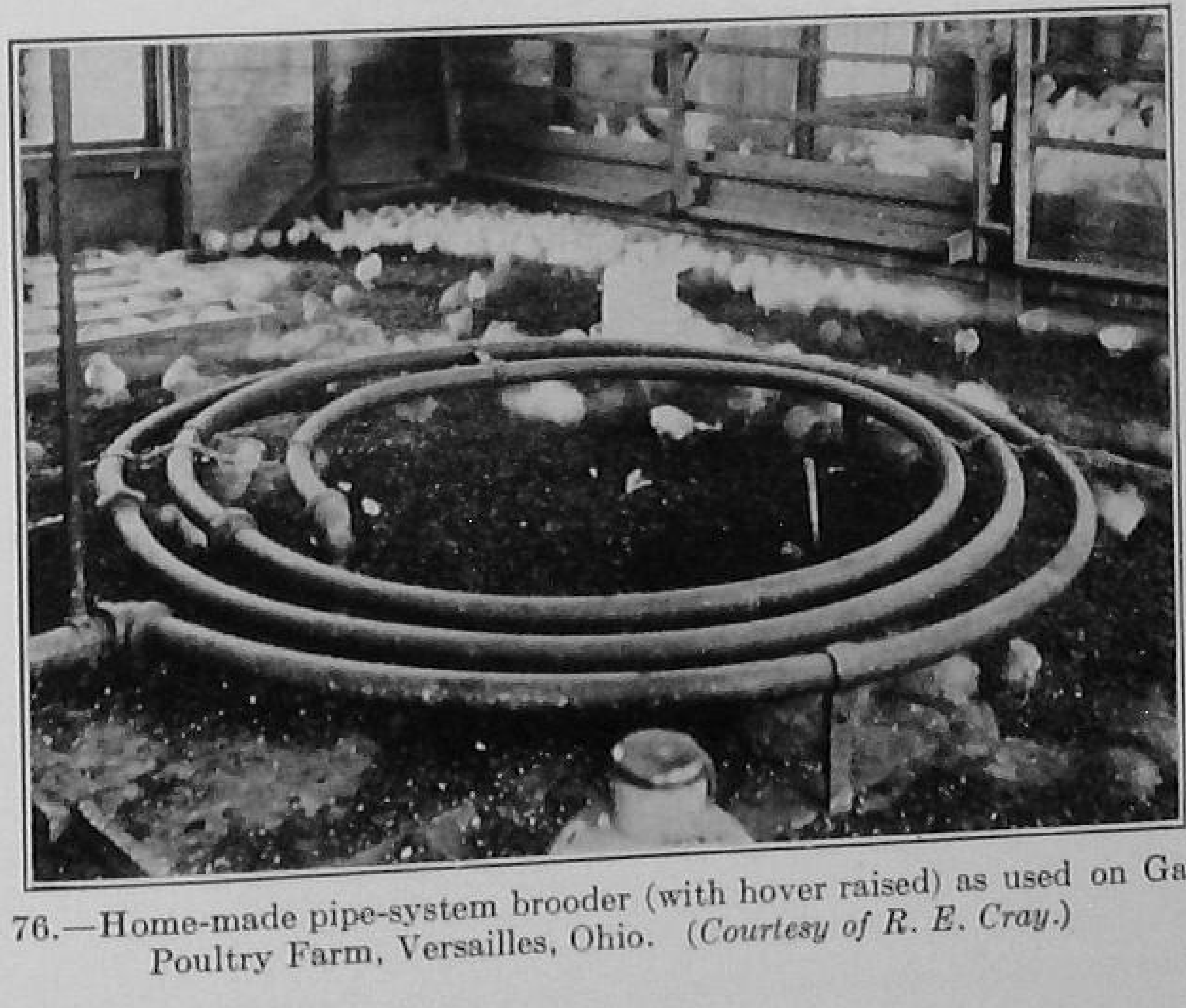


FIG. 76.—Home-made pipe-system brooder (with hover raised) as used on Gasson's Poultry Farm, Versailles, Ohio. *(Courtesy of R. E. Cray.)*

Unless only pullet chicks are bought, the cockerels need to be separated from the pullets. The age at which this is done will naturally vary with the breed being kept, but whenever it is done it is the common practice to remove the cockerels from the flock and to leave the pullets on the range. This gives the pullets additional, usually much-needed room, but it has the distinct disadvantage that while the cockerels that are soon to be marketed as

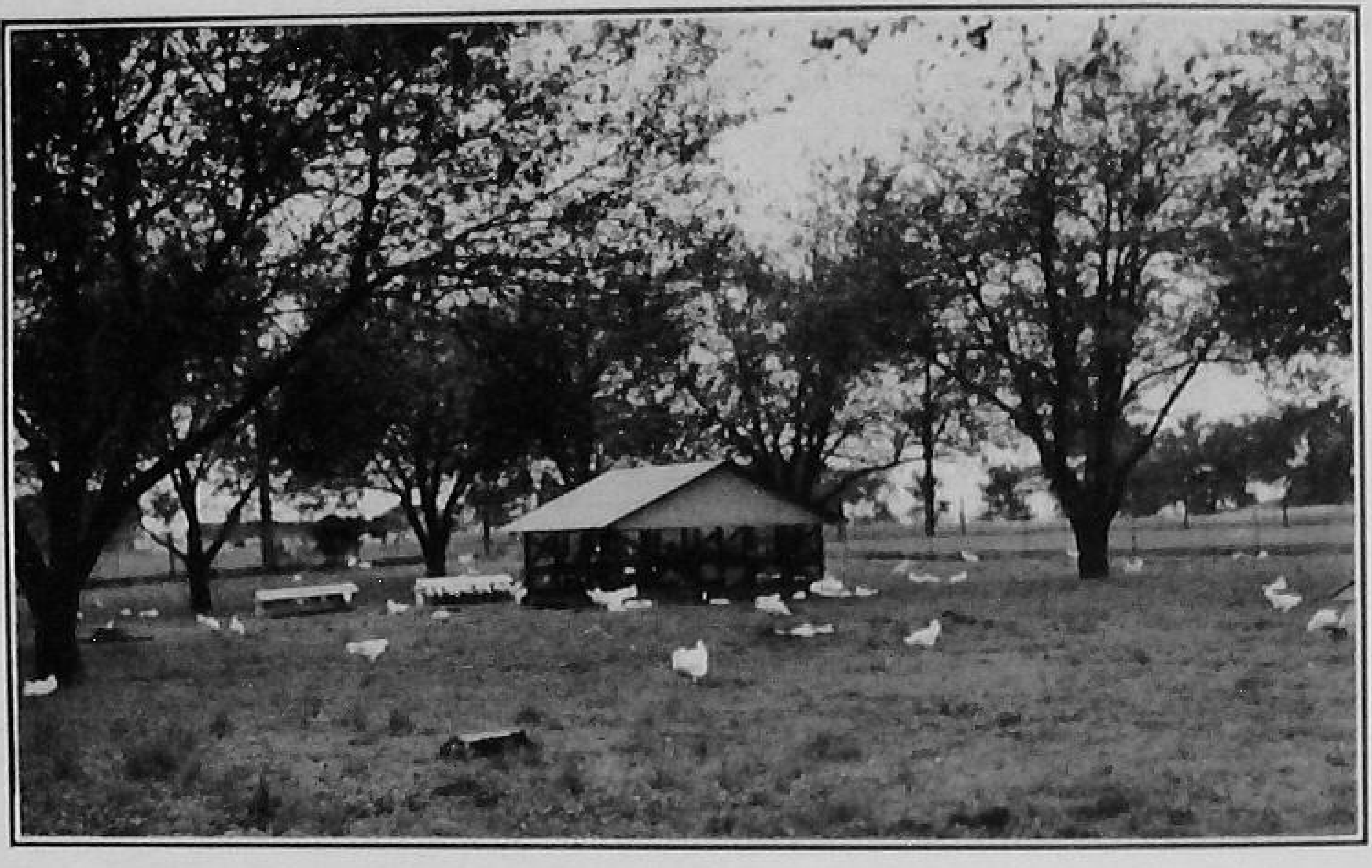


FIG. 83.—An all-purpose type of range shelter. The sides may be enclosed by the use of panels. (*Courtesy of Illinois Agricultural Experiment Station.*)

FIG. 84.—Inside view of a light weight range shelter. (*Courtesy of Poultry Tribune.*)

broilers are often taken to a new area, the pullets, on which the poultryman must depend for his main income, are left to grow up on the range that has been run over by all the chickens during the early part of the season. A more ideal arrangement would seem to be to limit the amount of range area used during the first part of the season to a reasonable minimum, and then at the time the sexes are separated, to remove the pullets to a clean range, leaving the cockerels in the old quarters until they are ready for market. In order to accomplish this objective in a practical way, more and

FIG. 85.—Brooder houses are easily moved on snow with either tractor or team. (*Courtesy of Poultry Tribune.*)

more poultrymen are making use of roosting sheds or range shelters for the pullets. These are simply frame sheds provided with a tight roof and wire sides. The only interior equipment needed is roosts. They may be provided with wire floors in order to keep the pullets from coming in contact with the night droppings.

HOW CHICKENS GROW

Standards of comparison are valuable in nearly every sort of work, and the measurement of chick growth is no exception. One must remember, however, that there is probably a normal rate of growth for each different breed and strain; that it will not be the same for males and females within a particular strain; that it will be affected

by time of hatching and that whether or not a particular lot of chickens equals or exceeds the standard will depend on the kind and amount of feed supplied, as well as on many other environmental factors. Maximum rates of growth are usually obtained with crossbred males raised indoors with limited exercise, and fed rations that are nutritionally adequate in all known respects.

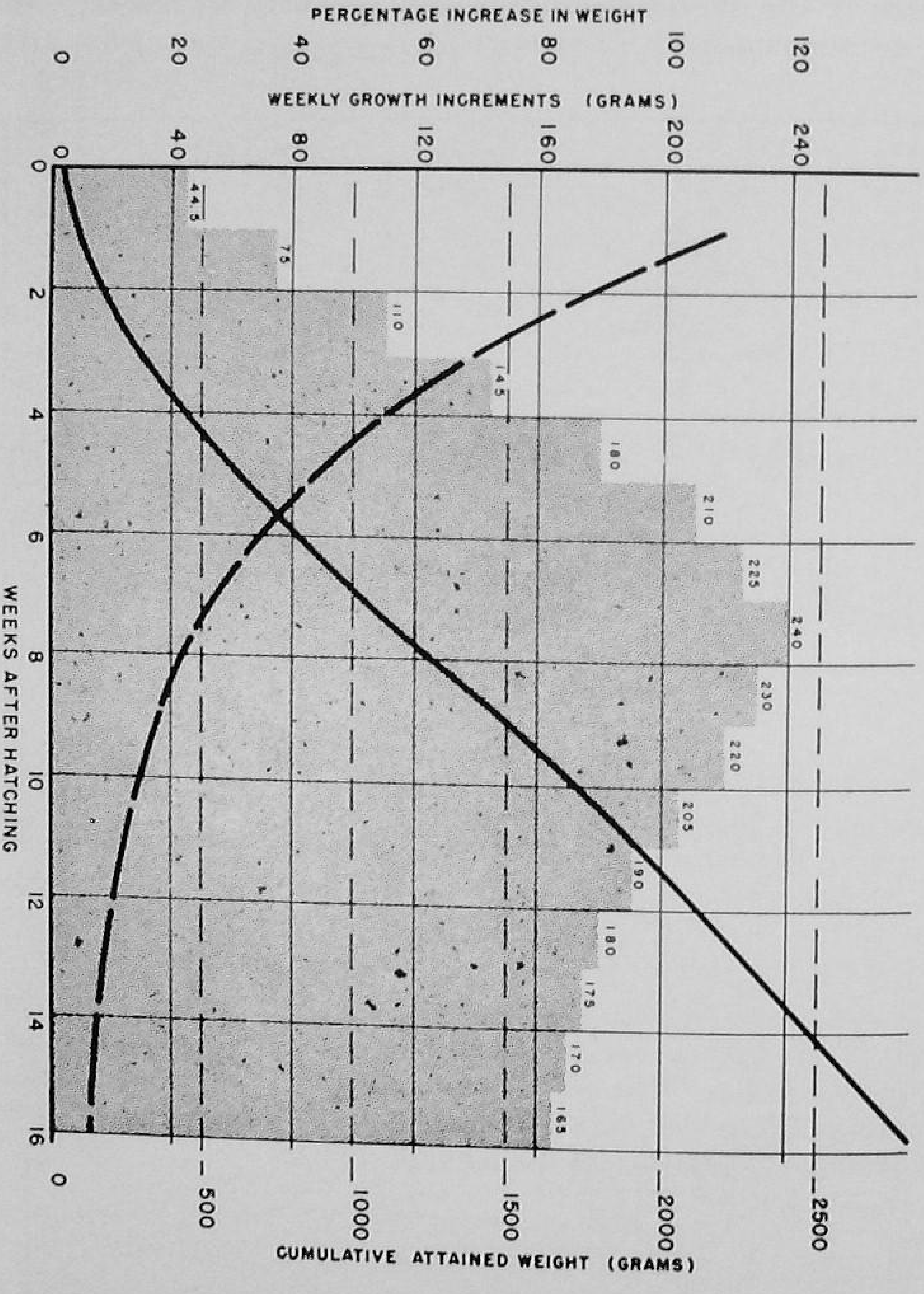


FIG. 86.—Chickens make rapid growth if given the right kind of feed. See text for description.

In Figure 86 are shown graphically the growth data for a group of crossbred males from hatching time to sixteen weeks of age. Three different measures of growth are included. The average weekly increases in body weight are shown as columns. The weekly incre-

ment (time-rate of growth) increases regularly till a maximum gain of 240 grams is reached during the eighth week. Thereafter the weekly increment becomes steadily less with each succeeding week. It should be said here that the weekly gains made by a flock of chickens, or by any individual in a flock, are often highly erratic, up well above the "standard" in one week, and down the next. This graph is intended to show average "expected" weekly increases rather than actual weights, although it was derived from several series of actual growth data.

The cumulative total, or attained weight, from week to week is shown as a solid line rising from left to right. A different scale is used here in order to get both measures on the same graph.

Finally, the rate of growth is shown as the percentage which each weekly gain is of the weight at the beginning of that week. Note that although the time-rate of growth increases from hatching to eight weeks of age, the percentage-rate of growth decreases from the very beginning.

TABLE 19.—DATA FOR THE GROWTH OF NEW HAMPSHIRE × BARRED PLYMOUTH ROCK CROSSBRED MALES SHOWN GRAPHICALLY IN FIGURE 86.

Age in weeks	*Average weight grams*	*Weekly gain grams*	*Rate of gain per cent*
0	40.5	—	—
1	85	44.5	110
2	160	75	88
3	270	110	69
4	415	145	54
5	595	180	43
6	805	210	35
7	1030	225	28
8	1270	240	23
9	1500	230	18
10	1720	220	14.5
11	1925	205	12
12	2115	190	10
13	2300	185	9
14	2480	180	8
15	2655	175	7
16	2825	170	6.4

Time of Hatching.—Several stations have studied the effect of out-of-season hatching on the growth and performance of White Leghorns—New York (1919–1921), Oklahoma (1923–1925), New Mexico (1924–1926) and New Jersey (1936–1940). Results were in agreement in that spring-hatched pullets made the best growth, laid the most eggs and, where egg weights were recorded, laid a lower percentage of small eggs, than did pullets hatched at other seasons. Conditions of feeding and management in those years were not the equal of those available now, but it seems clear that fall and winter-hatched pullets were at a disadvantage in the matter

of egg size, primarily because they were subjected to the influence of increasing length of day before they reached adult size and consequently began to lay at a younger age. The result was a large number of small eggs.

A recent report from the Delaware station shows somewhat comparable results with New Hampshire pullets hatched each month in the years 1946 and 1948. The pullets hatched in November through February averaged more than 10 per cent of eggs, for the laying year, which weighed under 22 ounces to the dozen. The May

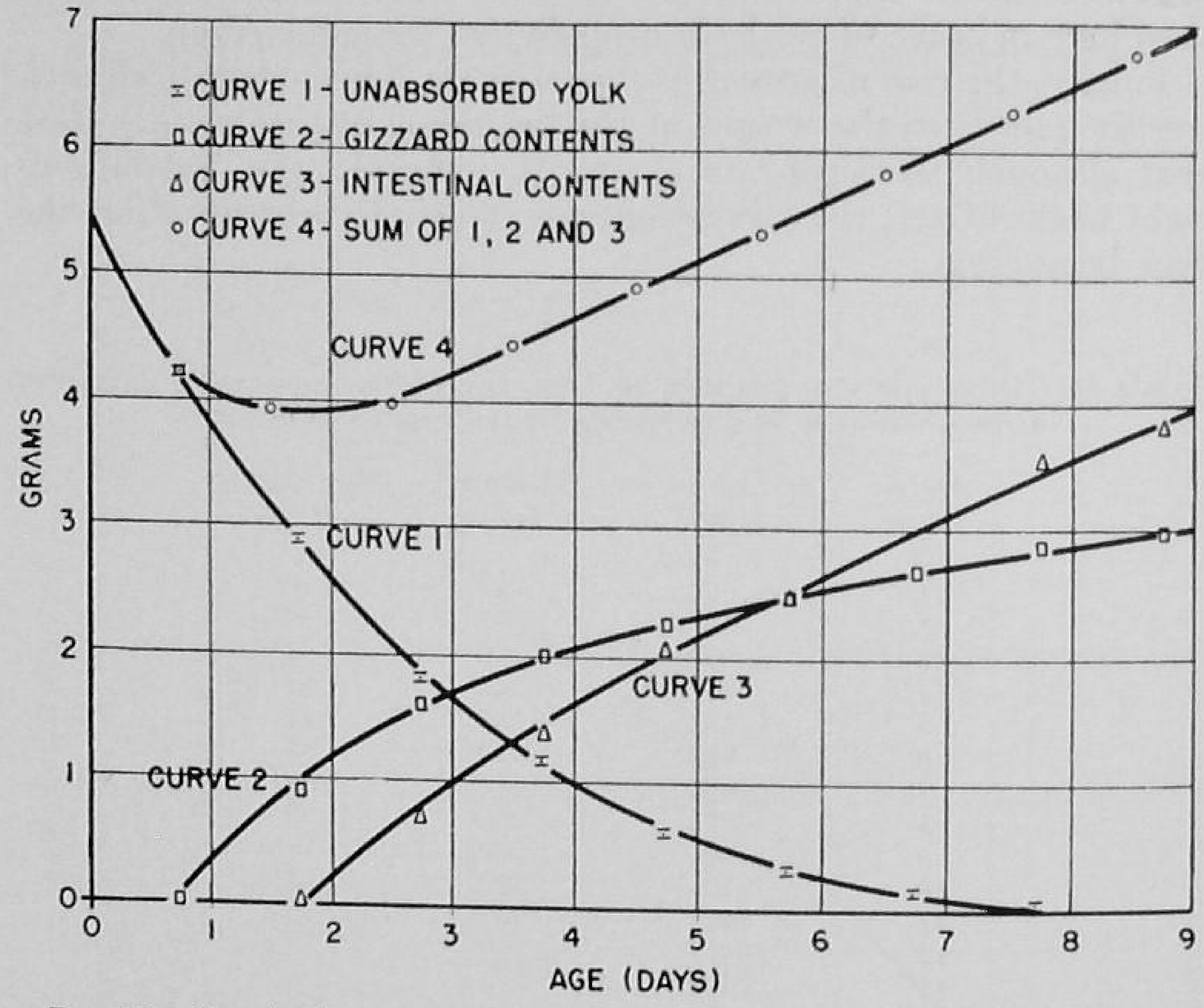


FIG. 87.—Showing how unabsorbed yolk affects chick weight during the first few days after hatching. (*After Barott and Pringle.*)

hatch produced 46 per cent small eggs during the first month of laying, but by the third month they were down to 2 per cent. The December hatch, by contrast, produced 84 per cent small eggs in the first month and were still laying 20 per cent small eggs in their fourth month. The May hatch reached 25 per cent production by the time they were 189 days old, but the December group was laying at this rate at 147 days. Since small eggs are worth less on the market than large eggs, this difference in performance needs to be given careful consideration before deciding on extensive out-of-season hatching.

The effect of time of hatching on returns is shown for 100 Central Indiana poultry flocks in Table 20. It is important that pullets be hatched early enough so that they will be laying at a high rate during the season of favorable egg prices in late fall and early winter.

TABLE 20.—TIME OF STARTING CHICKS AS RELATED TO RETURNS—100 CENTRAL INDIANA POULTRY FLOCKS, 1945–46. (DATA OF JOHNSON, ROBERTSON AND SICER.)

	Time of hatch		
	Before April	*April*	*After May 1*
Number of flocks	70	20	10
Average number of hens	159	155	131
Eggs per hen	158	151	158
Per cent of hens culled during year	67	54	52
Average price of eggs (cents)	39	38	38
Labor returns per hour (cents)	45	32	−2
Labor returns per 100 hens (dollars)	94	74	−8

CAPON PRODUCTION

The purpose of caponizing is to improve the quality of poultry meat. Farmers regularly castrate calves, pigs and lambs, but usually consider caponizing a much more difficult operation because it involves opening of the abdominal cavity. Actually, the operation is very simple and the method can be learned quickly by almost anyone.

A small flock of capons could be raised to advantage on many farms, either for family use or for sale to local customers. Larger flocks often compete seriously with laying hens and pullets for house room, which is one important reason why they are not often found on general farms. Unless they can be kept for two to four months beyond the time at which the cockerels would normally be sold as roasters, it is not worth while to take the trouble to caponize.

Selection of Cockerels to Caponize.—The size and condition of the young cockerels to be caponized is more important than their age or variety. Leghorn cockerels make excellent small capons, and Plymouth Rocks, Orpingtons, Rhode Island Reds, and various crossbreds are all suitable for large capons. It is very important that the operation be performed before the cockerels become too large. This means choosing heavy breed cockerels weighing 1 to $1\frac{1}{2}$ pounds, or Leghorns weighing $\frac{3}{4}$ to 1 pound. The most common error is to attempt the operation on larger cockerels, with consequent higher mortality and more slips, or incompletely castrated individuals. Only rapidly growing, vigorous cockerels should be chosen.

Preparation for the Operation.—It is always desirable to withhold feed for 18 hours and water for the last 12 hours prior to the operation, in order that the intestines may become empty and thus

permit better vision into the body cavity. There is also much less danger of puncturing the intestines during the operation.

Performing the Operation.—A first requirement for successful caponizing is good light. Bright daylight, preferably not in direct sunshine, is ideal. Artificial light may be used, if necessary.

Some means of restraining the birds in a convenient position must be provided. The usual procedure is to fasten the wings and legs by straps or cords so that sufficient tension can be applied to hold the bird well stretched out. If both testicles are to be removed through one incision, the bird should be placed on its left side.

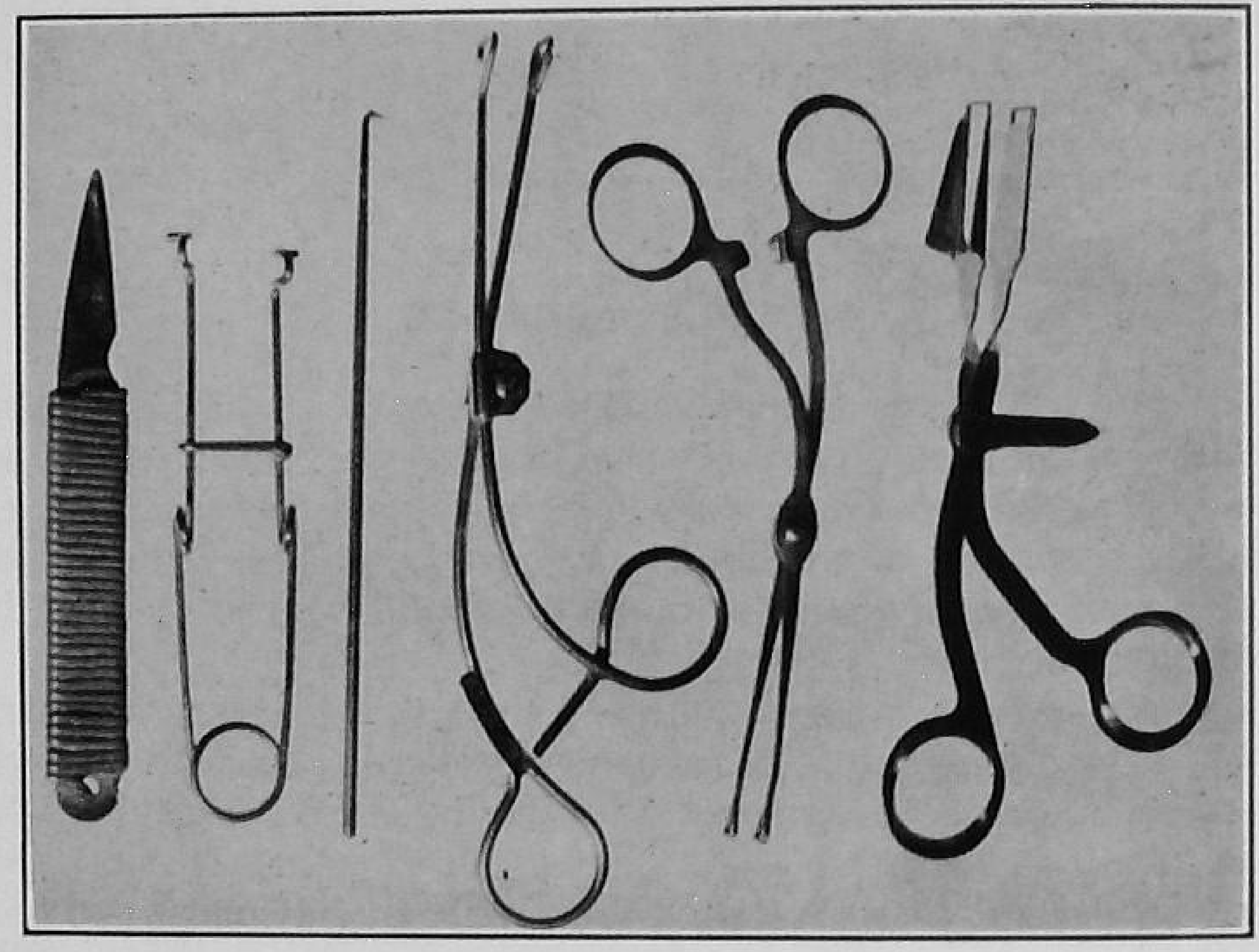


Fig. 88.—Instruments used for caponizing. Left to right: knife, spreader, tearing hook and probe, forceps for removal of the gonads, small forceps for operating on 2-week old cockerels, and an All-In-One instrument. (*Courtesy of Kansas Agricultural Experiment Station.*)

The instruments needed are a sharp knife or scalpel, a small probe which has a tearing hook on one end, a spreader for holding the ribs apart after the incision has been made, and a remover for taking out the testicles. Several different types of removers are available, but a forceps type is preferred by most operators.

Making the Incision.—It is usually necessary to pluck a few feathers from the area through which the incision is to be made. A little cold water may be used to moisten the surrounding feathers so that they will lie down out of the way. Next, find the last two ribs with the fingers of the left hand; slide the skin upward and backward toward the thigh, making sure that the underlying thigh muscles are out of the way; force the knife through the skin and

flesh between the last two ribs; lengthen the incision to about 1 inch, keeping it centered between the ribs and not too near the back; and insert the spreader so as to hold the ribs about ½ inch apart. If the knife has not severed the peritoneal membranes, they should be torn with the hook so as to expose the testicles to the view of the operator.

Removing the Testicles.—The lower, or left testicle should be removed first. It is not visible, as a rule, and must be lifted into view by the forceps before it can be grasped. The entire organ and the connecting portion of the spermatic duct must be taken out in order to prevent the bird from becoming a "slip." Care must

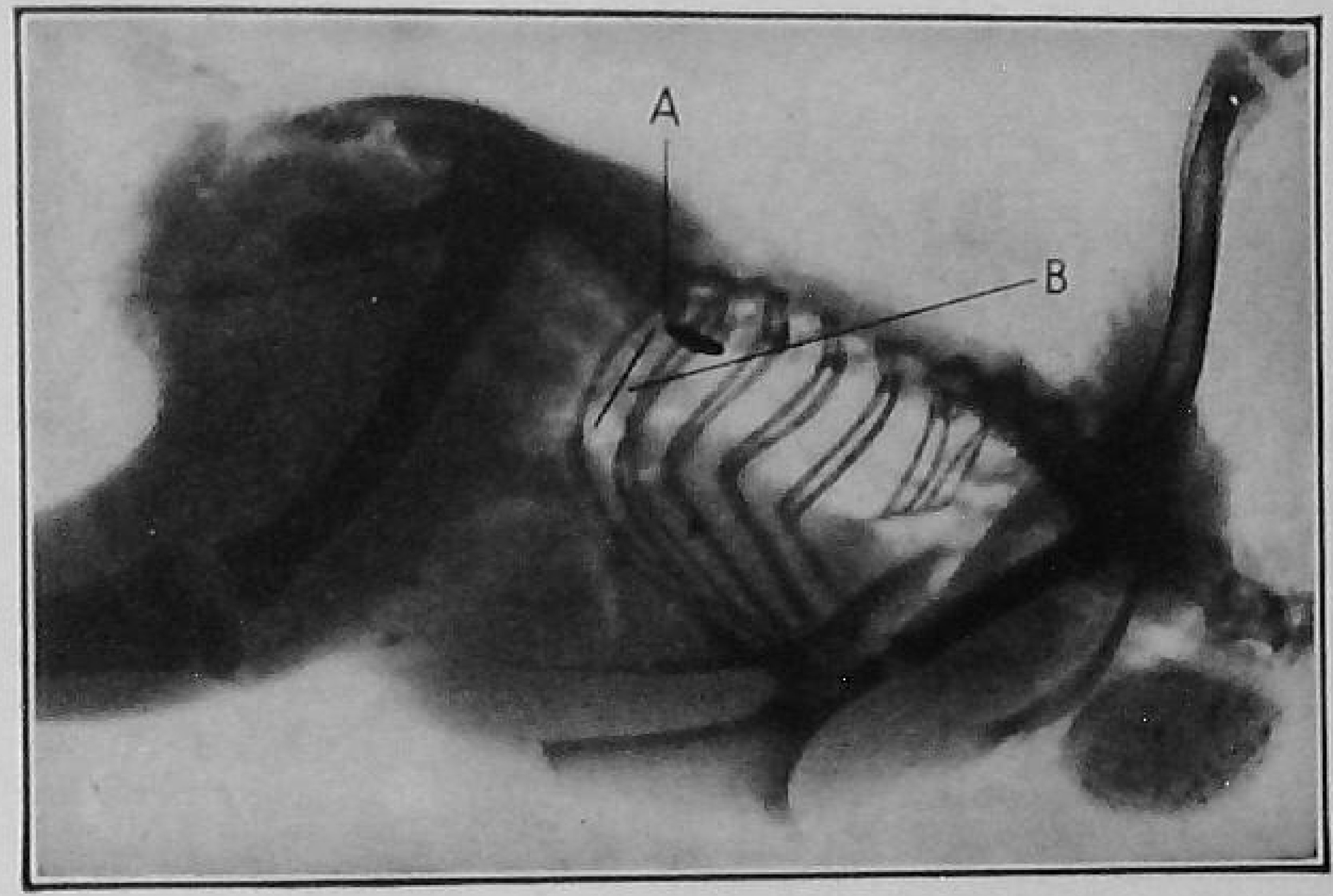


Fig. 89.—Radiograph of a living cockerel. The right testicle has been sketched in at *A*. The line of incision is indicated at *B*.

be taken, however, not to rupture any of the primary blood-vessels, or internal hemorrhage will result in death before the bird is removed from the operating table.

The remover is carefully worked over the testicle and so manipulated as to enclose the entire organ. It is then drawn out with a slight twisting motion. The same procedure is followed with the upper testicle. As soon as the spreader is removed, and the tension on the bird released, the skin and thigh muscles slip back over the incision, affording natural protection.

Because of the relatively high body temperature of chickens, it is possible to perform this sort of operation with little danger of infection. Ordinary cleanliness is all that is required.

Care After the Operation.—No special care of young capons is necessary, other than to give them a clean pen and range area where they do not have to compete with other chickens. Any good growing ration will be satisfactory.

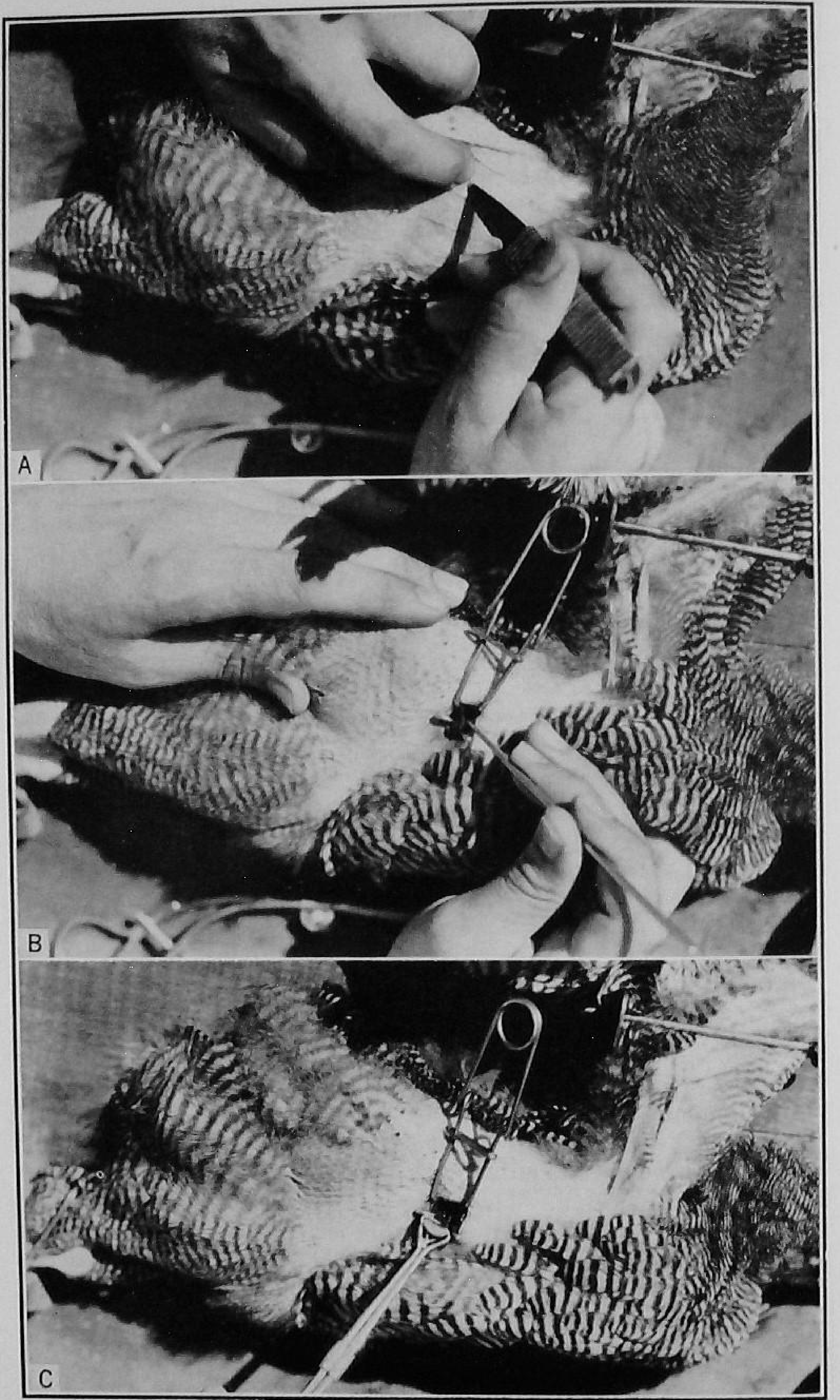


Fig. 90.—Performing the operation of caponizing. *A*, The skin and thigh muscle being drawn back preparatory to making the incision; *B*, tearing the peritoneal membranes after inserting a spreader to hold the ribs apart; *C*, removing the testicle. (*Courtesy of Kansas Agricultural Experiment Station.*)

Wind puffs often develop because air escapes from within the abdominal cavity before the incision between the ribs is healed, and becomes trapped beneath the skin. It is sometimes necessary to puncture these puffs four or five times on alternate days following the operation.

Slips result when some portion of the testicle is left in the body cavity. Occasionally a testicle is dropped inside the body after having been torn loose. If it is not removed, the bird will become a slip and will have all the external appearance of a normal cockerel. This is because the testicle, or in other cases a very small portion of it, becomes attached to the inner abdominal wall and continues to secrete the male sex hormone in sufficient quantity to cause enlargement of the comb and wattles and later toughening of the flesh.

Marketing Capons.—Persons who have once enjoyed roast capon of top quality are likely to be repeat customers year after year, and there is undoubtedly a potential market for capons which has never been explored. Common practice, however, has been to produce capons largely for local consumption. A few persons have developed a nice business in the sale of started capons, operated on at three weeks of age and sold at five or six weeks to customers who grow them to market age.

It should be clear that it is the presence of the hens, and their consumption of feed and water, which creates the moisture problem. In tests at the New Hampshire station it was found that litter samples taken from empty houses in January and February contained about 15 per cent of moisture, while those from pens filled with laying hens averaged about 35 per cent for insulated houses and ranged up to more than 60 per cent in uninsulated houses.

Vaporized Water and Heat Loss.—In addition to the water excreted in the droppings, there is a considerable amount of water which leaves the body by vaporization from the lungs. Since fowls have no sweat glands, there is very little opportunity for heat loss by evaporation from the skin. The amount vaporized from the lungs and air sacs varies widely with environmental temperature and humidity. It may also be influenced indirectly by the kind of feed.

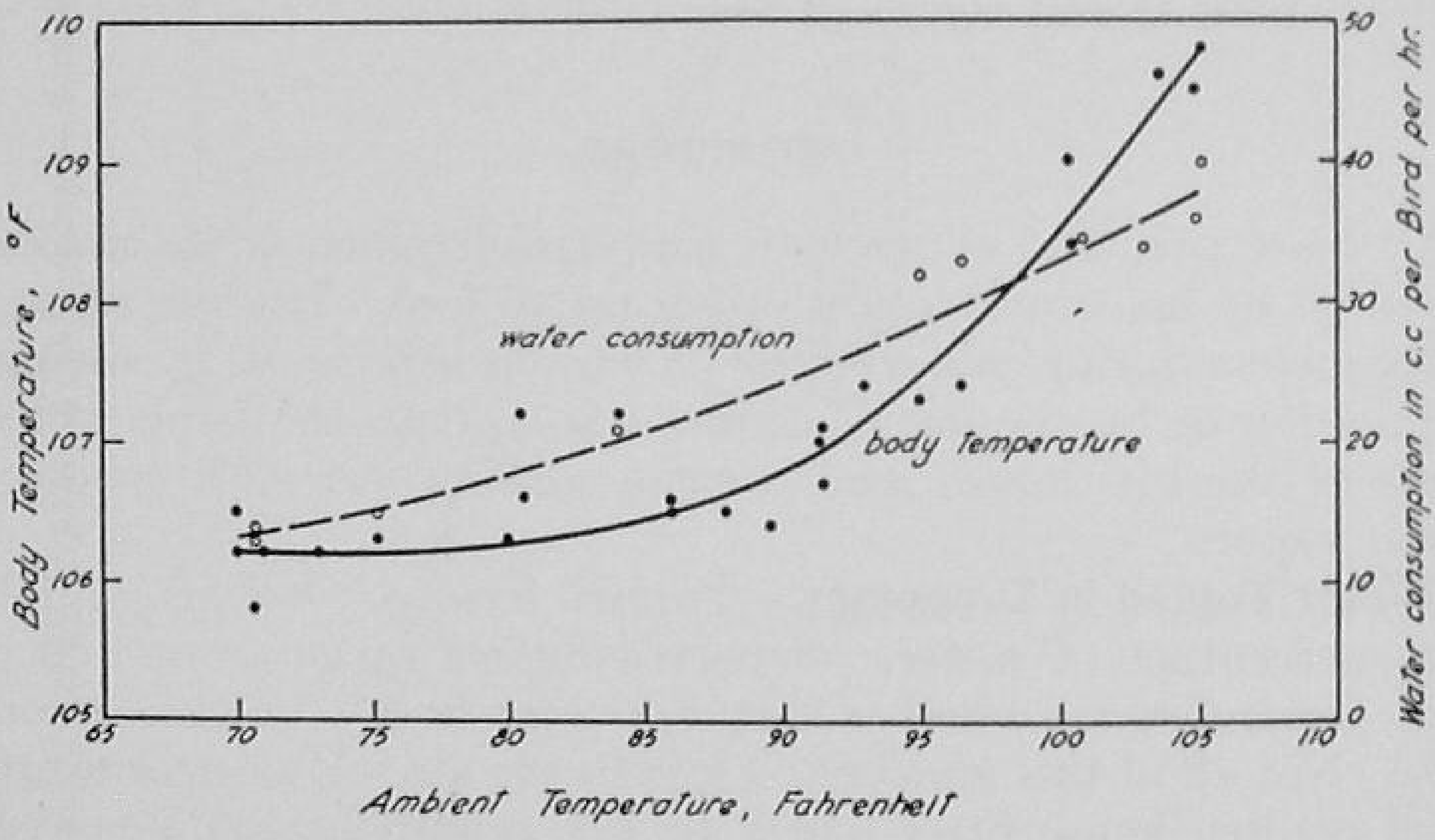


Fig. 95.—Effect of ambient temperature on body temperature and water consumption of White Leghorn pullets. (*After Wilson.*)

Vaporization of water removes heat,* and variation in the quantity vaporized (indicated in the fowl by the rate of panting) is therefore an important means of varying the necessary heat loss from the body. At high air temperatures—approaching the normal body temperature—it is the only means by which the fowl can lose a substantial amount of heat. At low air temperatures, on the other hand, only a small fraction of the total heat loss is of this character—at 40° F. about 10 per cent and at 20° less than 5 per cent.

Increased heat production, from whatever cause, increases the amount of heat lost as heat of vaporization. At high temperatures, especially when relative humidity is also high, fowls soon reach the limit of normal physical regulation and must resort to panting to

* Each quart of water vaporized at body temperature dissipates about 2150 B.t.u. of heat.

facilitate vaporization of water as the only means of losing heat rapidly enough to keep the body temperature from rising. This condition exists whenever the surrounding air temperature equals or exceeds the skin temperature so that heat can no longer be dissipated by radiation. If the air temperature rises still higher, vaporization must also serve to rid the body of heat absorbed from the hot environment. This obviously cannot continue for long, and the fowl dies from heat exhaustion. Panting will result in a very marked increase in the respiration rate as the fowl attempts to get rid of

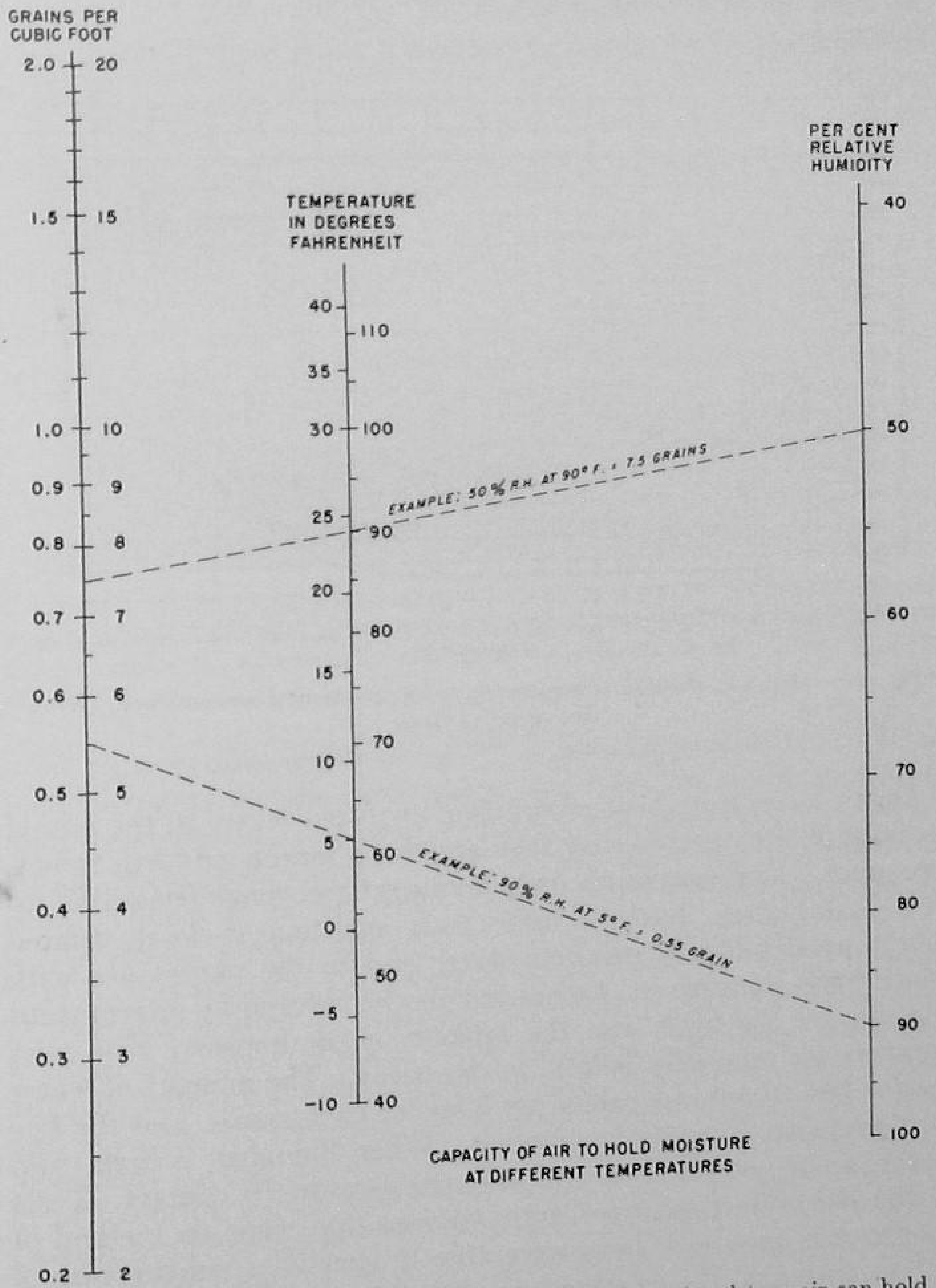


FIG. 96.—Chart for quick determination of the amount of moisture air can hold at different temperatures and relative humidities.

more and more heat by this means. The amount of water vaporized increases slowly at temperatures of 75° to 80° F., and very rapidly thereafter, provided the humidity of the inspired air is low enough to permit. With inspired air at very low relative humidity but at temperatures of 105° F. or above, some records indicate a short-time evaporative moisture loss of 25 to 30 grams per hen per hour, along with very watery droppings. If the inspired air is both warm and saturated, the hen is completely unable to avoid collapse and death. The difficulty of eliminating excess heat, while maintaining other body processes, begins to show at air temperatures of about 85° F. Egg size decreases, egg shells become thinner, and production is reduced.

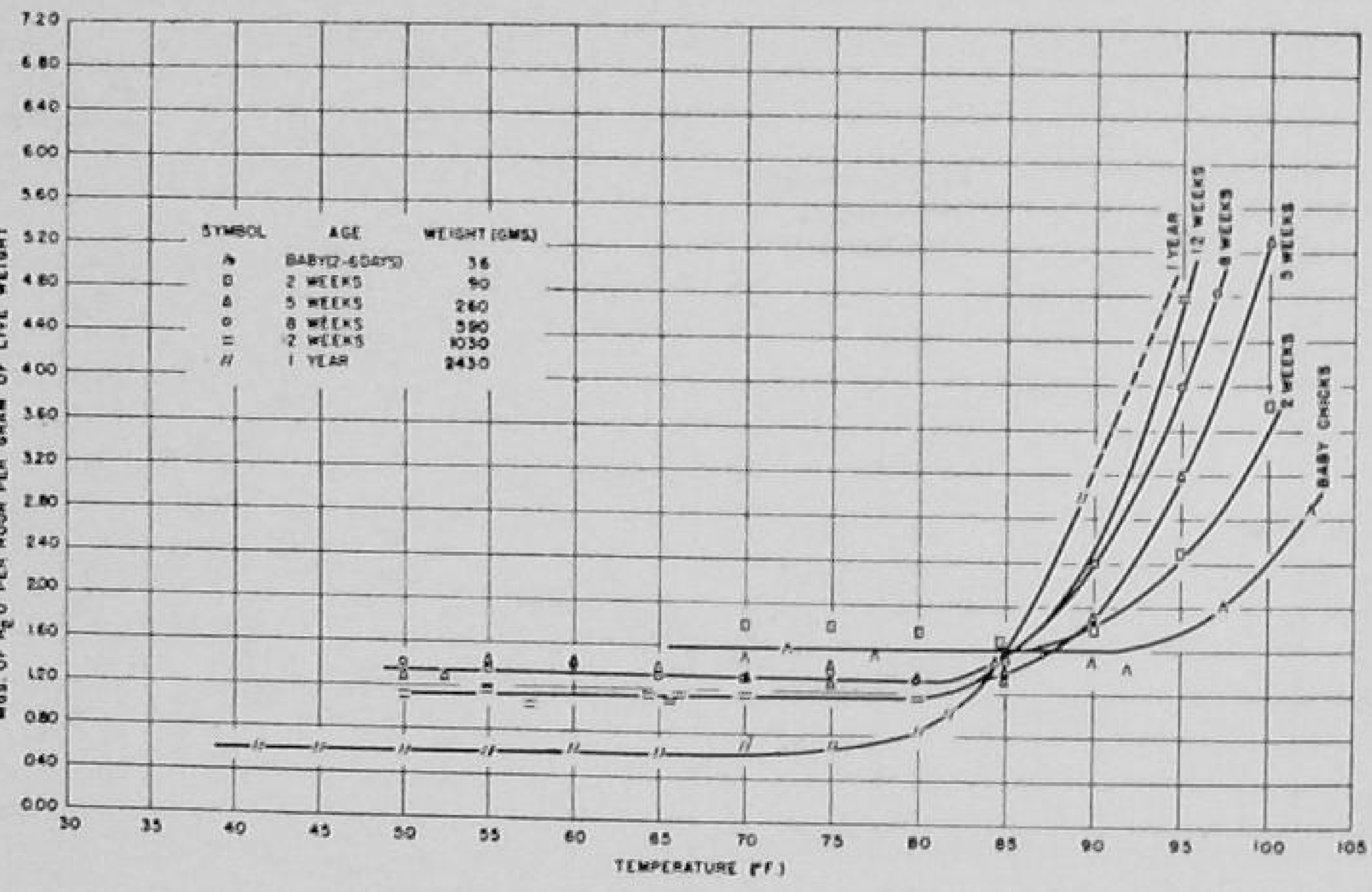


Fig. 97.—Relation of water of respiration to environmental temperature. (*After Barott and Pringle.*)

Death losses from heat prostration are often severe in the humid sections of the country, and they are also a serious problem in hot, dry areas where maximum daily temperatures range from 105° to 115° F. or higher. Survival under such conditions is closely related to the availability of drinking water and to the persistence with which fowls consume it. Losses can also be reduced by intermittent spraying of the fowls and the interior of the houses. Fine mist sprayers are especially helpful in dry areas. The amount of water used is low, about one gallon per hour for each nozzle, and the fine mist promotes evaporative cooling. When humidity is high, cold water can be used to lower the body temperature by contact. Tests at the Beltsville Research Center showed that when no method of cooling was provided, hens were able to survive a temperature of 90° F., provided the relative humidity did not exceed 75 per cent. At 95° they survived at humidities below 60 per cent, but at 100° F.

they survived only if the humidity was 30 per cent or lower. Very fat hens succumbed first, probably because the air sacs were constricted and therefore unable to function efficiently in evaporating water from the body tissues.

At low temperatures, on the other hand, the heat loss due to vaporization of water shows little change from normal. Most of the heat loss is then in the form of sensible heat, by radiation and convection, and it is therefore available for warming the air in the hen house. When laying hens are on full feed, the excess heat available for maintaining the normal body temperature is adequate for air temperatures above 40° F. When such hens are active, as during the day, and are producing additional heat because of muscular activity, the critical point is lowered to about 20° or perhaps even to 15° F.

FIG. 98.—Keeping laying hens without a house at the U. S. Poultry Experiment Station, Glendale, Arizona. The roosts are unprotected, while the trap nests, feed hoppers, and water vessels are located beneath a palm-leaf shade. (*After Heywang and Jull.*)

At temperatures below 15° or 20° F. hens must draw on stored or food nutrients for the heat energy necessary to maintain normal body temperature, and egg production will therefore be lowered. Inside temperatures of 8° to 10° F. will cause egg production to drop as much as 25 per cent. Combs begin to freeze at about 6° above zero in dry air, and at 9° to 10° above zero in moist air.

It is clear that the compensatory range above the "comfort zone" of thermoneutrality (in which the animal feels neither hot nor cold) is much less than the range below and that fowls, like other farm animals, have more defenses against cold than against heat. They are, however, handicapped by their small size, because they have more body surface per unit of weight. The effects of a sudden drop in temperature are therefore more severe than with larger animals. In a 5-pound hen about 95 per cent of the total body tissue is within $\frac{3}{4}$-inch of the surface of the body. By contrast, in a 1000-pound steer only about 25 per cent of the total body tissue is so exposed.

VENTILATION

Ventilation is seldom a problem with average farm poultry flocks except during cold weather. At other times of the year the hens are permitted to run outside or the windows are open so that there is adequate and continuous change of air. Many commercial flocks, however, are housed continuously in buildings which require year-round ventilation of some kind. Ventilation systems in actual use include the following:

1. Open front, with no means of temperature control.
2. Adjustable windows or cloth-covered frames, or both, which may be opened according to weather conditions.
3. Baffled or louvered openings, usually with no provision for adjustment of air movement.
4. Rafter ventilation, *i. e.*, adjustable openings between rafters. Used most often with insulated houses.
5. Slot ventilation—consisting of two long, narrow openings in the front wall, one at the top of the wall and one at the bottom of the windows. Used only with insulated houses.
6. Flue ventilation. Flues may be in various parts of the house, but both inlets and outlets must be provided. Common in multi-story houses. Insulation is essential to best results.
7. Combination systems as, for example, outlet flues capped with revolving ventilators, combined with inlet openings which discharge air into the house after it has passed through an attic or plenum chamber to raise its temperature above that of outside air. Insulated walls and ceiling would be essential to best results with this type of ventilation.
8. Completely automatic systems with positive air circulation and thermostatic controls.

The total air breathed by fowls at rest in a comfortable environment is about 1 cubic foot per hen per hour—slightly less for small hens and slightly more for large ones. For 100 5-pound hens this would be about 2400 cubic feet every 24 hours. Measured by air change in the average hen house, built for the convenience of the caretaker and not simply to accommodate the hens, this is a very small requirement. It is entirely overshadowed by the rate of air change necessary to remove moisture from a tightly-built house. In most instances, if ventilation is adequate to keep the house dry, it will much more than meet the air requirements of the fowls. Under conditions of heat stress, that is when both air temperature and relative humidity are high, the respiration rate is very rapid and the total volume of air breathed may be eight or ten times normal.

The amount of air which must be moved through a poultry house to carry out excess moisture will depend upon the inside and outside temperatures and the difference between them, and on the rela-

tive humidity of the inside and outside air. Raising the temperature increases the capacity of air to hold moisture. In the range of 30° to 75° F., each rise of 1° in temperature means an increase of about 5 per cent in moisture-holding capacity of the air. The amount of water vapor in a pound of saturated air at 5° F. is doubled at 20°, and redoubled successively at about 36°, 55°, 76° and 99°. For every grain or gram or pound of water vapor which air can hold at 5° F., it can hold 32 times as much at 99°.

TABLE 21.—VENTILATION REQUIREMENTS UNDER VARIOUS ASSUMED CONDITIONS.

Size of house (all 7 feet high)	10 × 10	20 × 20	30 × 30	40 × 40	36 × 100	30 × 200
Number of hens (5½ pounds each)	25	100	250	500	1200	2000
Cubic feet per hen	28.0	28.0	25.4	22.4	21.0	21.0
Square feet of exposed area per hen	15.60	10.00	7.32	5.76	4.89	4.91
Insulating value	4	6	12	10	16	8
Incoming air:						
Temperature	25° F.	15° F.	0° F.	5° F.	−5° F.	10° F.
Relative humidity	80%	90%	90%	85%	85%	95%
Outgoing air:						
Temperature	35° F.	40° F.	40° F.	40° F.	40° F.	50° F.
Relative humidity	80%	80%	85%	75%	85%	85%
Temperature difference	10°	25°	40°	35°	45°	40°
Pounds of feed eaten per 100 hens per day	19	21	23	25	27	29
B.t.u. of sensible heat per hen per hour	41	42	43	44	45	46
Manure per 100 hens per day (pounds)	36	40	44	47	51	55
Water lost to air in grains per hen per hour	31	35	38	41	45	48
Vaporized water in grains per hen per hour	23	23	23	23	23	23
Total water to be removed (grains)	54	58	61	64	68	71
Minimum air flow to remove moisture:						
Cu. ft./hen/hour	82	42	31	39	32	26
Changes per hour	3.0	1.5	1.2	1.7	1.5	1.2
Maximum air flow which will not lower the house temperature:						
Cu. ft./hen/hour	10	0.65	23	34	35	27
Changes per hour	0.36	0.02	0.9	1.5	1.7	1.3

NOTE: Actual exposed area increased by an amount equal to 10 per cent of the floor area, to allow for increased heat loss through glass. Vaporized water calculated as 0.6 milligram per hour per gram of live weight. Weight of manure calculated as 1.9 times the weight of feed consumed. Water loss from manure assumed to be 30 per cent of the total weight of manure. Heat required to warm incoming air estimated as 1 B.t.u. per degree rise for each 50 cubic feet of air. The above calculations show that some of the assumed conditions are impossible to maintain.

If, for example, the relative humidity of outside air at any given temperature is 70 per cent, and that inside the poultry house at the same temperature is 80 per cent, the outside air contains $12\frac{1}{2}$ per cent less moisture than the inside air, and forced ventilation of the outside air through the building will remove the excess moisture. But if the relative humidity of both the inside and the outside air is at 80 per cent, no amount of air change will do any good. Either the temperature of the outside air must rise so that it can hold more moisture, or its humidity must drop, if mere air circulation through the house is to remove any moisture. This state of near equilibrium between inside and outside humidity, often with an excess on the outside, is common in many poultry houses during mild winter weather, often for several days in succession. Since no change can be effected in the outside air, dampness in the house can be reduced only by (1) providing some means of absorbing moisture, such as built-up litter, (2) raising the inside air temperature by a small amount of artificial heat, or (3) providing sufficient insulation to retain the heat which the hens themselves produce.

Suppose, however, that the outside temperature is 15° F. with a relative humidity of 75 per cent, while the inside temperature is 35°, and that one wishes to keep the inside relative humidity from going above 75 per cent. If outside air is moved through the hen house at a not too rapid rate, it will be warmed to 35° and its capacity for carrying moisture will be more than doubled. At 15° and 75 per cent relative humidity, it would be carrying 0.75 grain of moisture per cubic foot. (See Fig. 96.) After being warmed to 35° it can carry 1.8 grains at the same relative humidity. Each cubic foot passed through the house can therefore pick up an extra grain of moisture, provided the rate of air movement is slow enough to prevent an appreciable drop in the temperature of the inside air. (If the incoming air is saturated, it will carry 1.0 grain per cubic foot at 15° F. It can then pick up but 0.8 grain more at 35° and 75 per cent relative humidity. But at a maximum of 85 per cent relative humidity, it could still pick up 1 grain per cubic foot.)

Assume that the foregoing conditions exist in a 40 × 40 foot pen or house 7 feet high and containing 500 $5\frac{1}{2}$-pound hens. The respiratory moisture given off by the flock, calculated at 0.6 milligram per hour per gram of live weight (see Fig. 97), will amount to 277,200 grains in 24 hours. If moisture released from the droppings is taken as 17 pounds per 100 hens per day, this will amount to an additional 595,000 grains each 24 hours, making a total of 872,200 grains of moisture to be removed. At one grain per cubic foot of air, it will take 36,300 cubic feet per hour, or 3.2 changes of air per hour, to remove the water vapor. This is not an excessive rate, since leakage and infiltration will cause about 2 changes per hour in any but very tightly constructed buildings. This example illustrates the method of estimating ventilation requirements.

INSULATION

The heat production of a fasting hen at rest is about 2.75 gram calories per hour per gram of live weight. For a 5½-pound (2495-gram) hen this amounts to 6861 gram calories or 27 B.t.u. per hour. Normal activity will cause an increase in heat production, and feed consumption will cause an additional increase proportional to the amount of dry matter consumed. With today's housing and management methods, the activity increment is probably about one-third of the basal heat production. This would add 9 B.t.u. per hour. For hens laying at a high rate, say 80 per cent, and therefore consuming about 30 pounds of total feed per 100 hens per day, with a dry matter content of 91 per cent, the increase in heat production due to feeding will be about 14 B.t.u. per hen per hour. This calculation is based on a heating effect of 68 Calories per 100 grams of dry matter consumed. Adding the three values thus obtained brings the total heat production for such hens to 50 B.t.u. per hour.

This is of necessity an approximation because of the variation in activity and feed consumption among individual hens, because of the regular diurnal variation in basal heat production with a minimum at about 8 P.M. and a maximum at 8 A.M., and because of reduced heat production during the variable roosting period. Furthermore, a reduction must be made to allow for the latent heat of vaporization, because of moisture in the expired air, which is not available for warming the air of the poultry house. At winter temperatures of 30° to 40° this is about 8 per cent of the total heat production. Deducting this amount leaves a figure of 46 B.t.u. per hen per hour, or 110,400 B.t.u. per 100 hens per day, which will be used in the examples to follow.

The lower total heat production of 4- or 4½-pound hens is, in practice, partly offset by the common procedure of keeping more such hens in a house or pen of given size. If hens are laying at a lower rate than is here assumed, the total feed consumption will be less, and the total heat production will therefore be lower. On the other hand, the amount of moisture to be removed by ventilation will also be lower.

Insulation Needed.—In a 20 × 20 foot house 7 feet high, the combined wall and roof area is about 960 square feet. Adding 40 square feet to allow for the extra heat loss through the usual window area gives 1000 square feet of exposed area, or 10 square feet per hen. The heat production just calculated amounts, then, to 4.6 B.t.u. per hour per square foot of combined wall and roof area. If walls and roof consist of a single layer of siding and roll roofing, the insulating value is about 2. By definition, this means that with a difference in temperature between inside and outside air of only 2° F., and with no direct ventilation, that is with the house tightly closed, the heat loss will be 1 B.t.u. per hour through each square foot of

Foundations.—A good foundation must be solid enough to support the building, deep enough to prevent heaving by frost, and high enough above grade to keep out surface water. In order to leave room for the opening and shutting of doors where a deep litter is used, the top of the foundation must be at least 6 inches above the floor level. This brings the tops of the door sills 8 or more inches above the floor. If for some reason it is necessary to locate the house where the texture of the ground is such that it tends to hold moisture, a tile placed even with the bottom and just at the outside of the foundation, and furnished with a suitable outlet is a necessary precaution if the house is to be dry.

Floors.—The hen-house floor must be moisture proof, free from cracks, and easily cleaned. It should be rat-proof and durable. A board floor, if properly laid, is free from cracks and is easily cleaned and disinfected. It is not a durable floor when compared with concrete, and it is not rat-proof unless raised well off the ground. While the air space below such a floor effectively stops capillary moisture, there are many times during the year when circulation of cold air beneath the house may make the floor so cold as to cause condensation of moisture from the warmer air inside the house. This "sweating" of the floor is a common cause of wet litter.

Concrete floors are dry if properly constructed. They are sanitary, durable and rat-proof. They are not cold when properly bedded with litter. In many parts of the country they have a valuable equalizing effect on the temperature inside the poultry house. The temperature of a wood floor remains within about 2° F. of the outside air temperature, for a temperature range of 25° to 95° F. A concrete floor, on the other hand, may be from 5° to 7° warmer than the air at low temperatures, and as much as 15° cooler than the air temperature when the latter is 90° to 95° F. This is a point of considerable importance in keeping fowls comfortable during hot weather.

Cement-sawdust concrete has been used for poultry house floors with varying degrees of success. It has a relatively short life, absorbs water readily, up to a maximum of 70 per cent of its dry weight, and varies greatly in strength according to the kind of wood from which the sawdust comes. It is most useful where no great strength is required, but where low cost, light weight, nail-holding ability, and resistance to fire and termites are important.

Walls and Partitions.—The walls and partitions must be solid enough to support the roof and withstand heavy winds. Wide variation is possible in the use of construction materials, depending on availability, cost, and the insulating value desired. The recent trend has been to eliminate partitions in many of the larger houses, thereby making larger pens. This makes it necessary to give particular attention to strength of the overall structure in order to avoid danger of collapse from heavy snow loads or in windstorms.

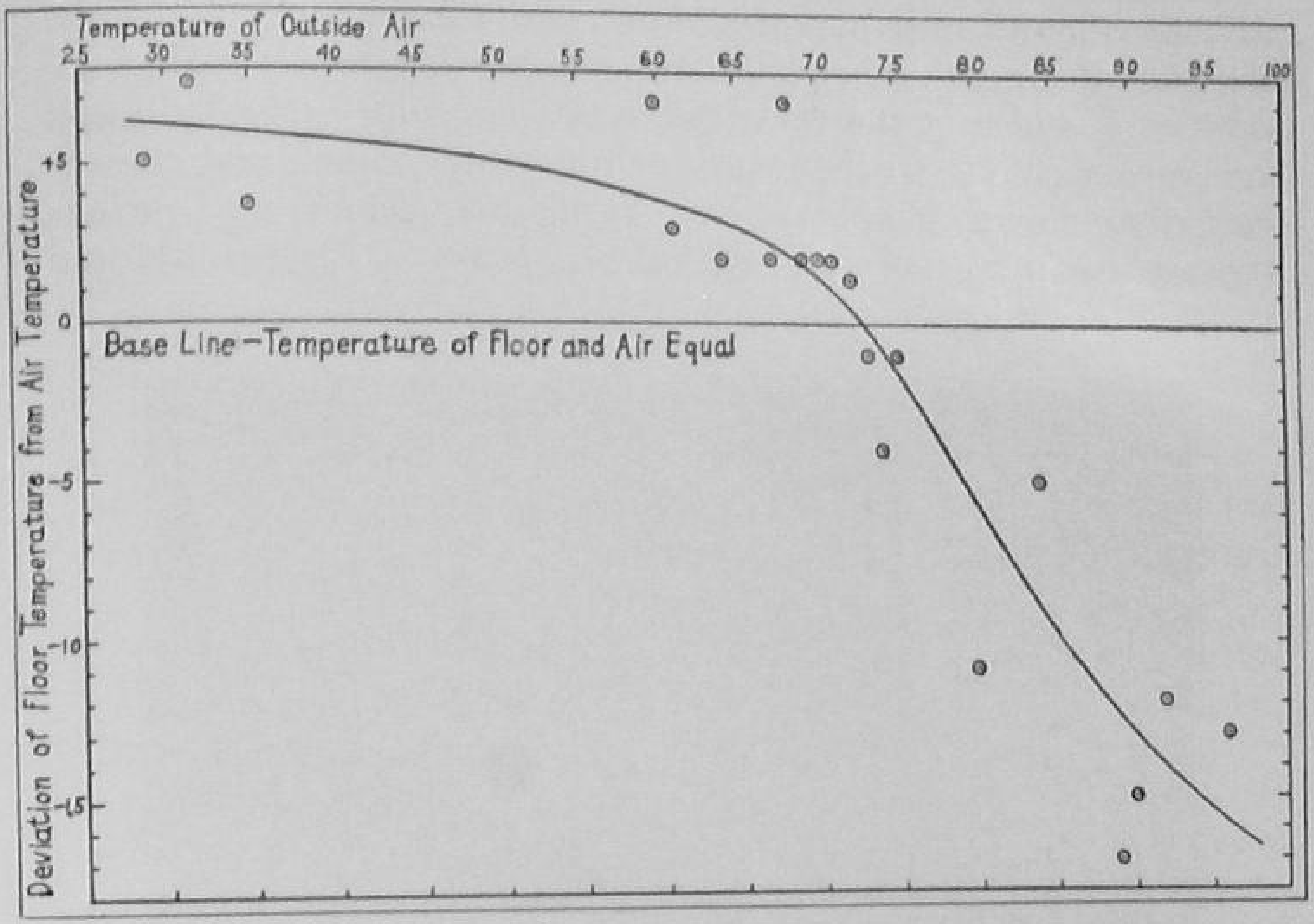


FIG. 102.—Curve showing difference between floor temperature and air temperature in a house with a concrete floor. (*Courtesy of Maryland Agricultural Experiment Station.*)

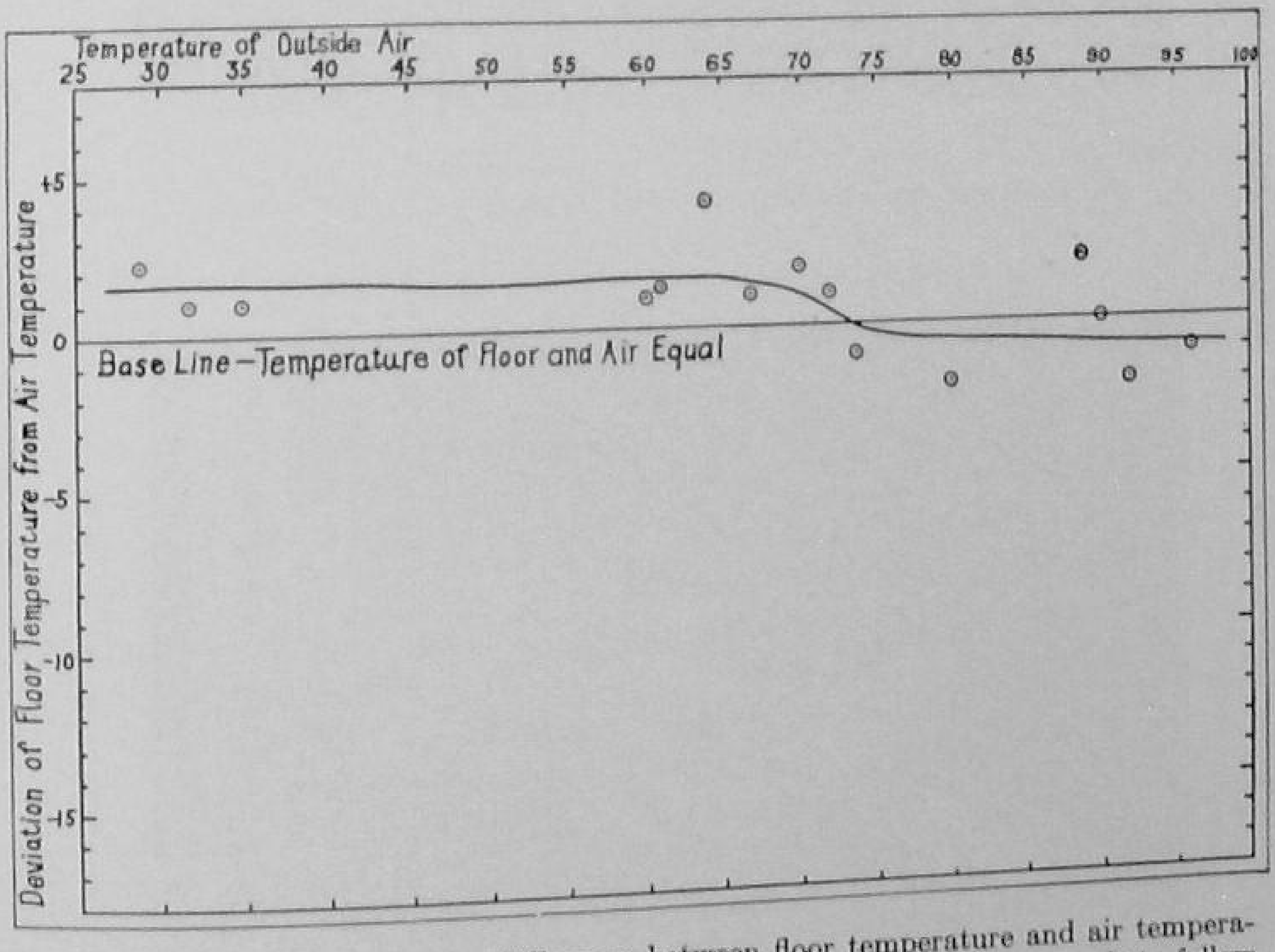


FIG. 103.—Curve showing difference between floor temperature and air temperature in a house with a board floor. The temperature of a wood floor tends to follow closely the temperature of the outside air. (*Courtesy of Maryland Agricultural Experiment Station.*)

Insulation.—It has become common practice to use some type of insulation in the construction of houses built for flocks of commercial size. Roof insulation helps in both summer and winter. Wall insulation is added in the colder parts of the country, the kind and amount depending on the length of the winter season and the expected minimum temperatures. Insulation values for various types of wall and roof construction are shown in Figures 106 and

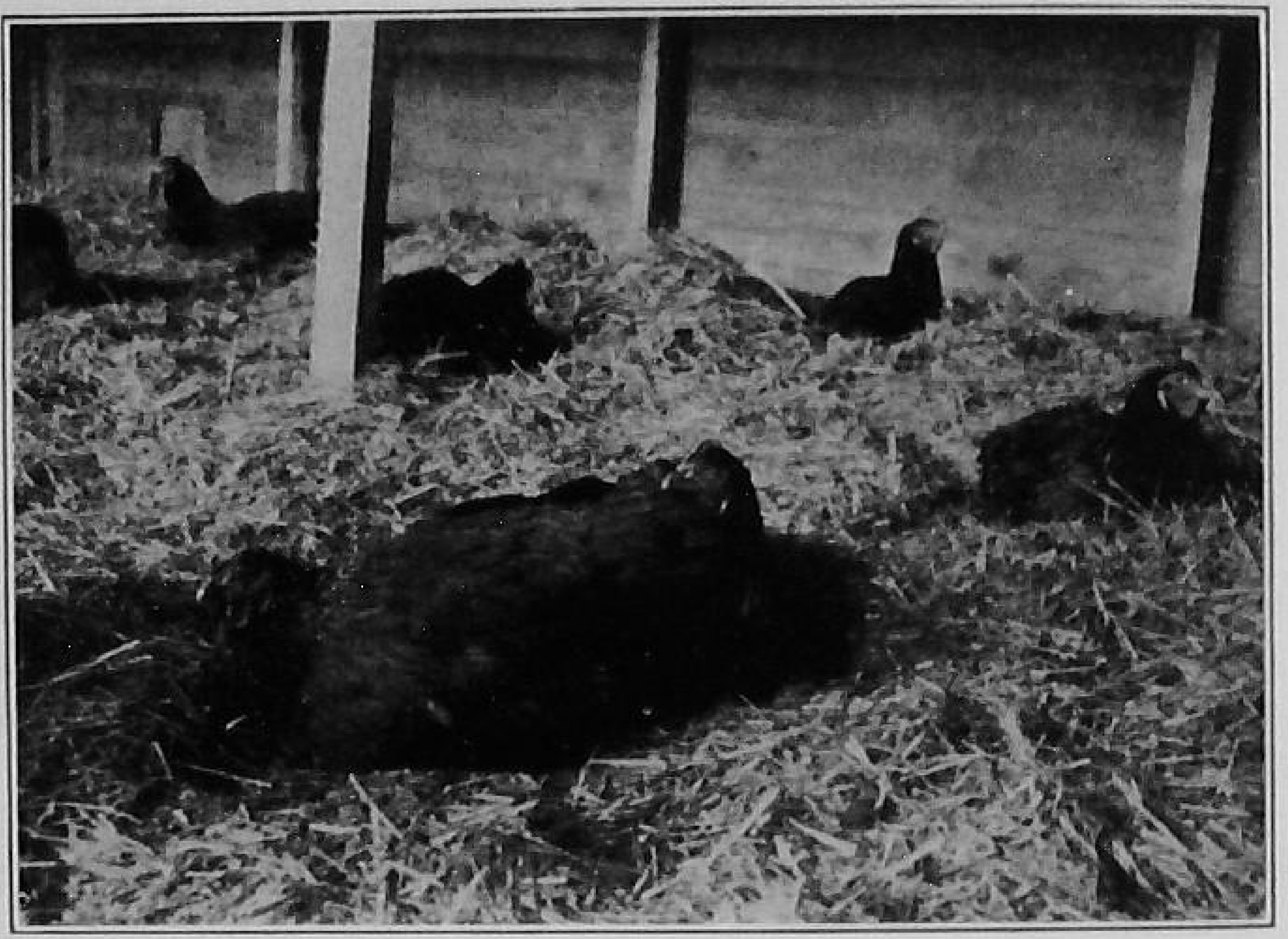


Fig. 104.—On a hot day—fowls snuggling down in the litter to make contact with the surface of the cool concrete floor. (*Courtesy of R. H. Waite.*)

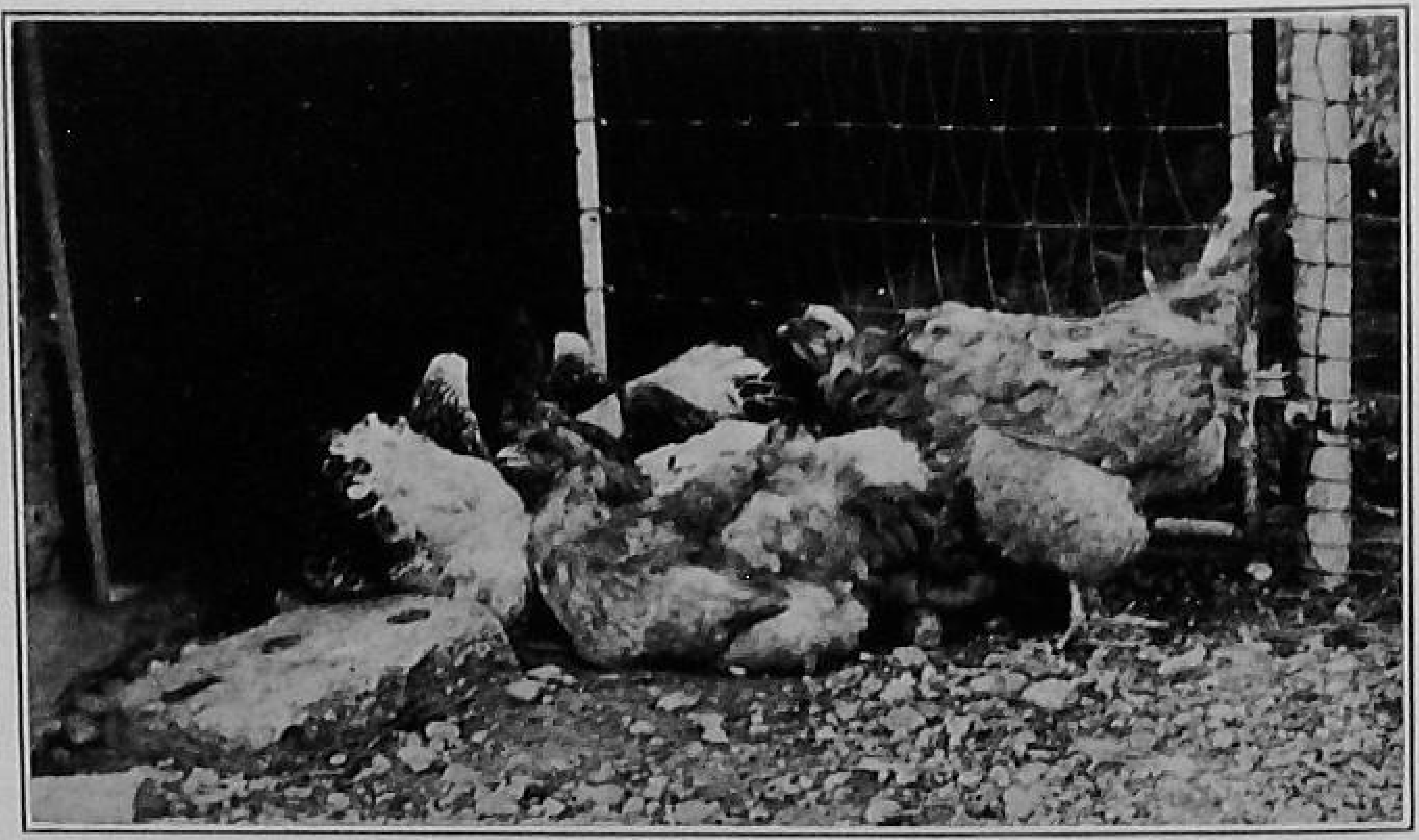


Fig. 105.—Fowls from a house with a wood floor seeking relief from the heat in a shaded corner of the run. They were photographed at approximately the same time as those in Figure 104. (*Courtesy of R. H. Waite.*)

107. The numerical values refer to the number of degrees difference in temperature which can exist between the warm and cold sides of a wall while just permitting 1 B.t.u. of heat to pass through an area of 1 square foot of wall in one hour. Engineers commonly use what is known as the "U" value, or coefficient of heat transfer. It is the reciprocal of the insulating value. Insulating values of 2, 4 and 8 are equivalent to U values of .5, .25 and .125, respectively.

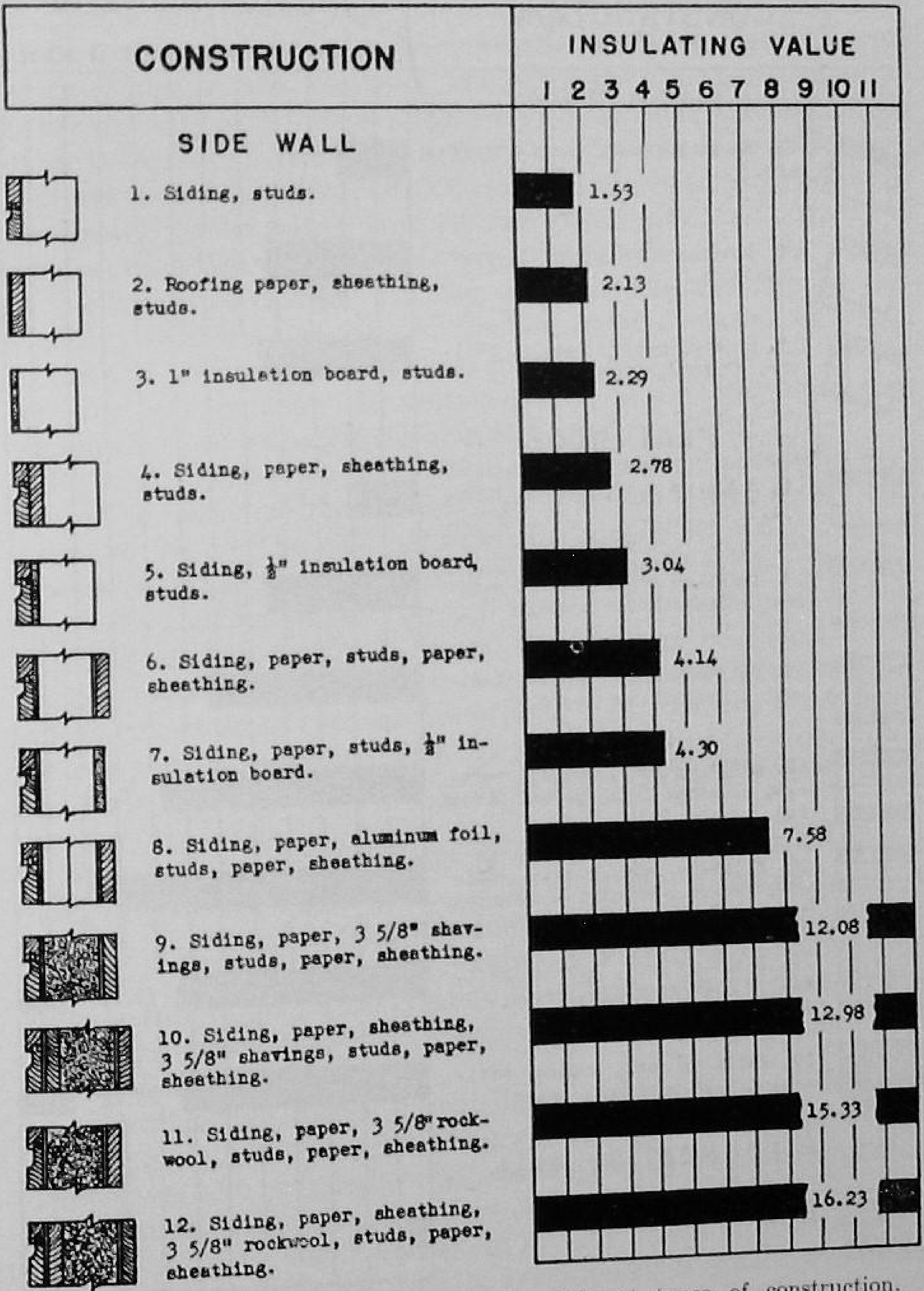


Fig. 106.—Side wall insulation values for different types of construction. (*Courtesy of Connecticut Agricultural Extension Service.*)

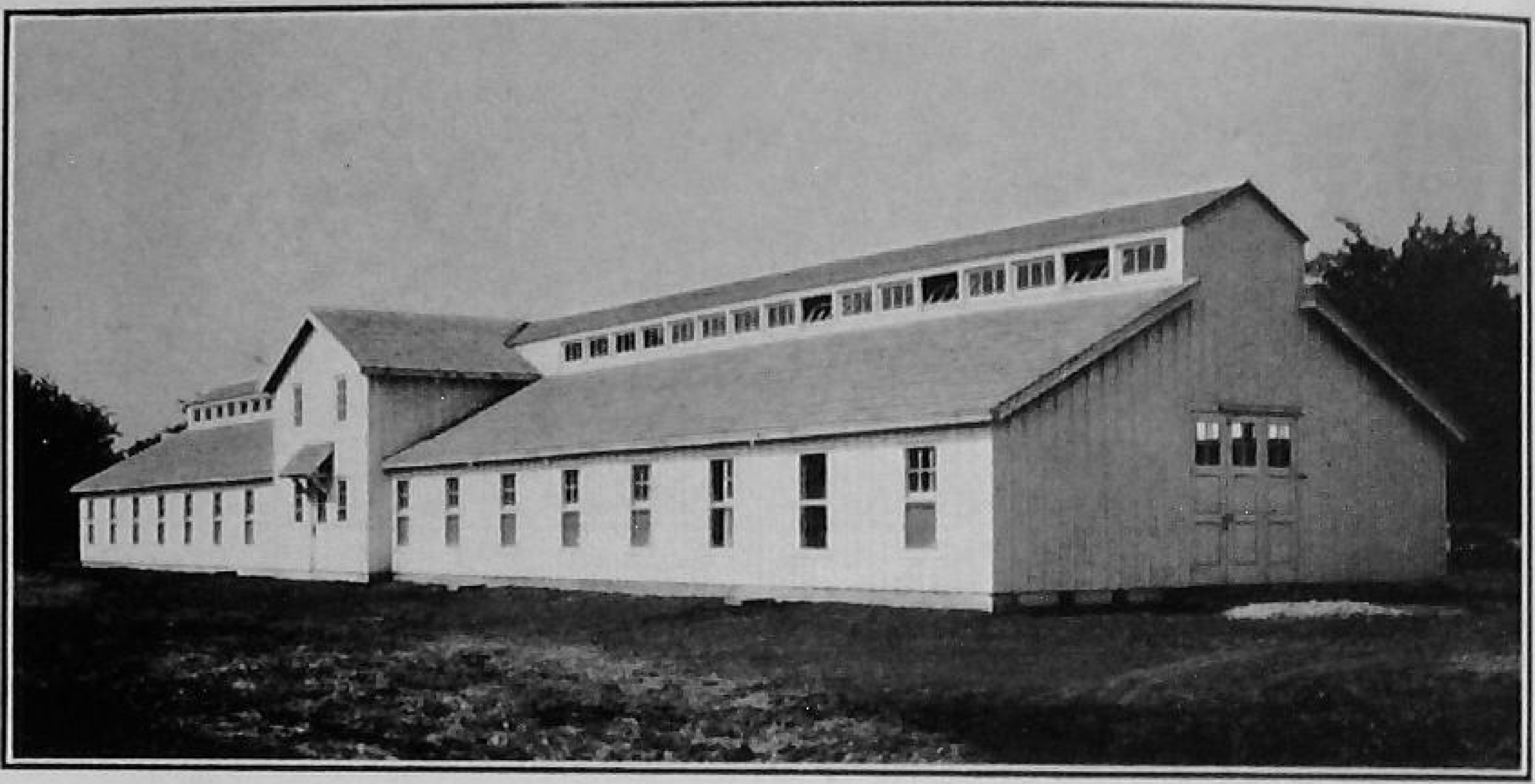


FIG. 111.—This house contains 32 breeding pens each 8 × 12 feet, and has an 8-foot central alleyway running north and south. (*Courtesy of Illinois Agricultural Experiment Station.*)

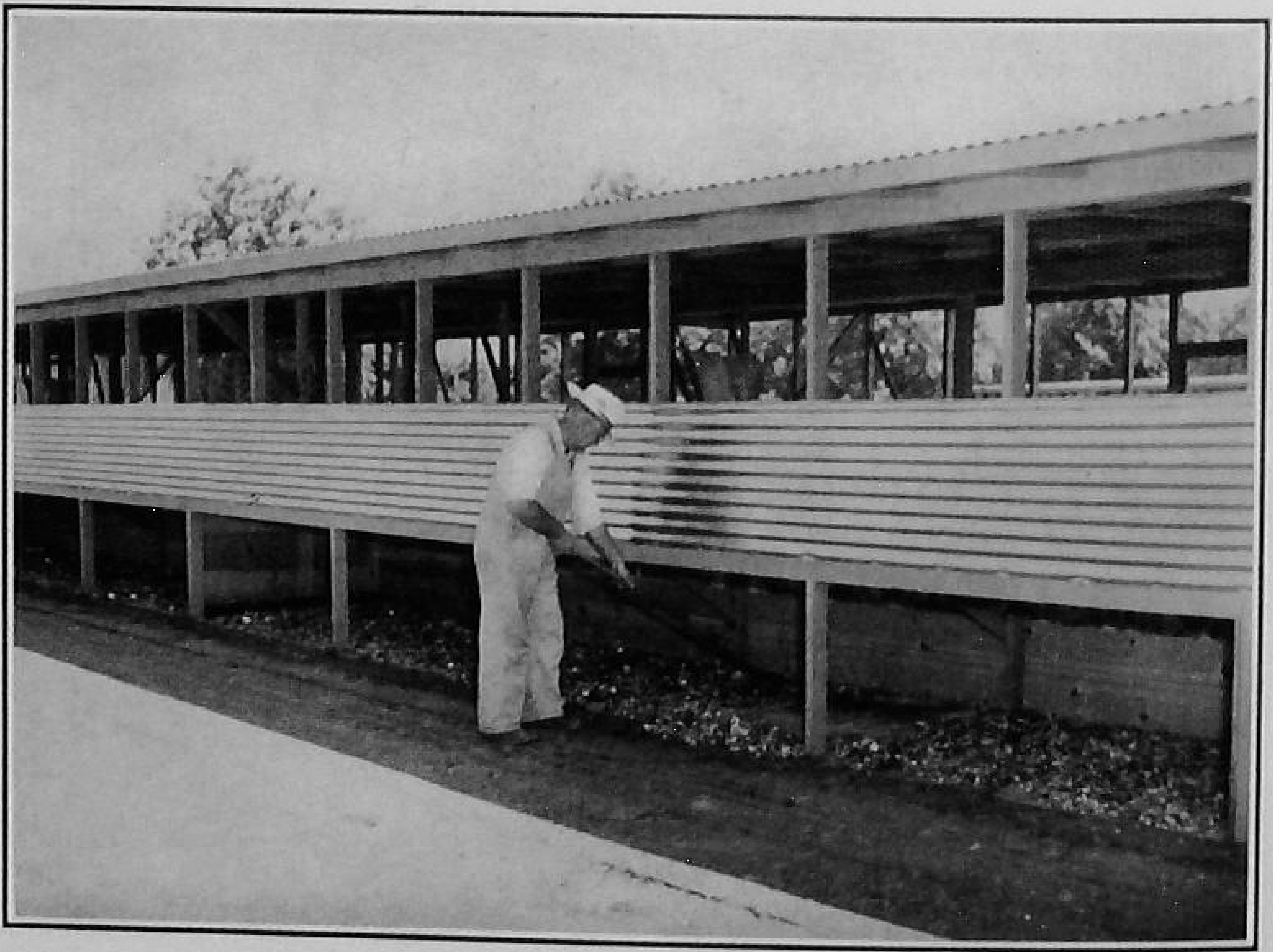


FIG. 112.—Droppings are removed from the rear in this 460′ × 24′ trap nest house for 3200 pullets on the Dryden Poultry Breeding Farm, Modesto, California. (*Courtesy of Horace Dryden.*)

Some poultrymen like the "community" type of nest, which is really a covered box about 2 feet wide and 6 feet long. It has no partitions, and there is an opening at each end through which the hens may enter and leave. A sloping cover is hinged for convenience in gathering the eggs. Such nests are often built on legs so that the entire unit can be moved out from the wall for better ventilation during hot weather. Each community nest will replace 10 or 12 individual open nests.

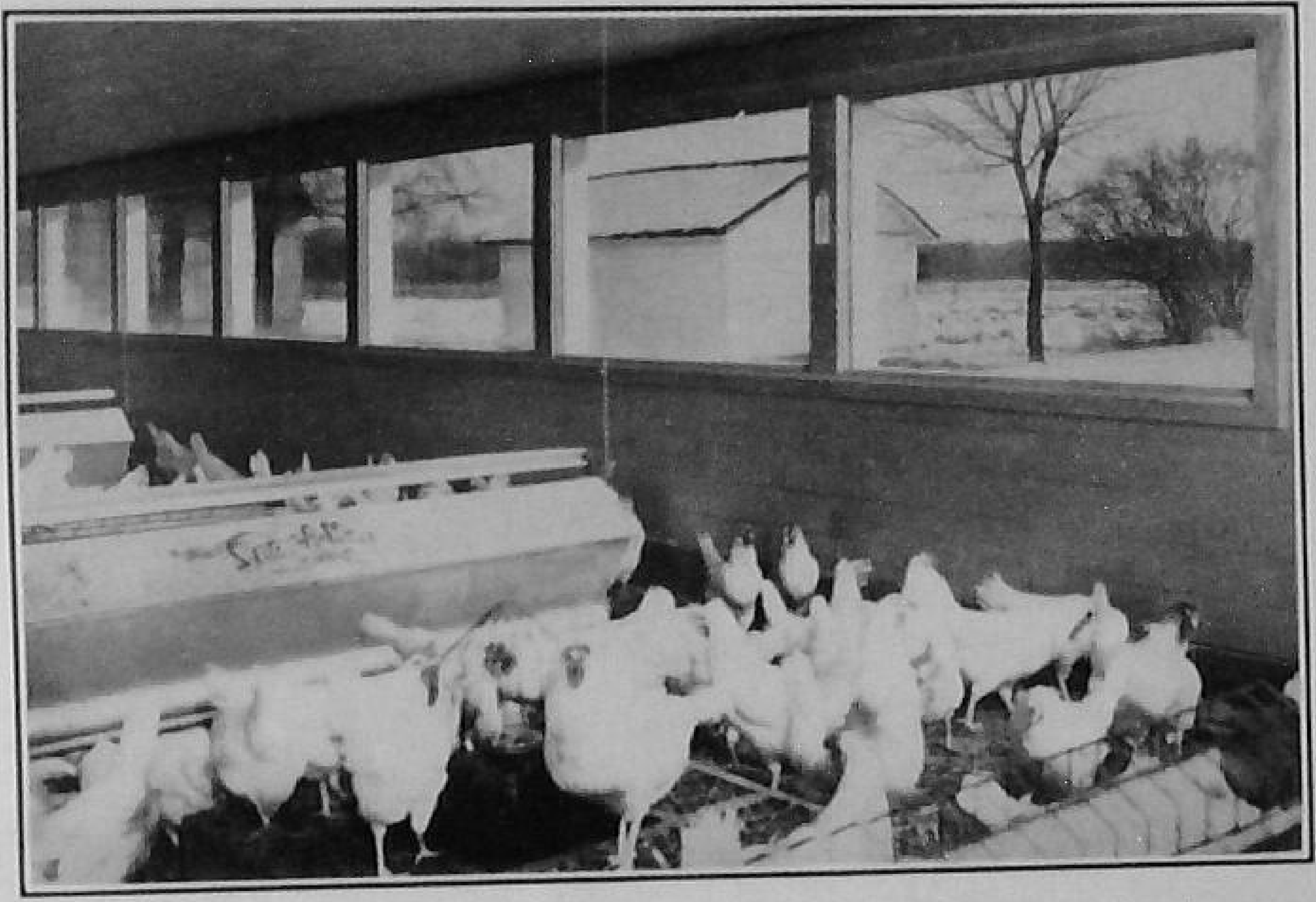


Fig. 113.—Double-wall insulating glass permits better lighting and reduces condensation on the inside surface to a minimum. (*Courtesy of Libbey-Owens-Ford Glass Company.*)

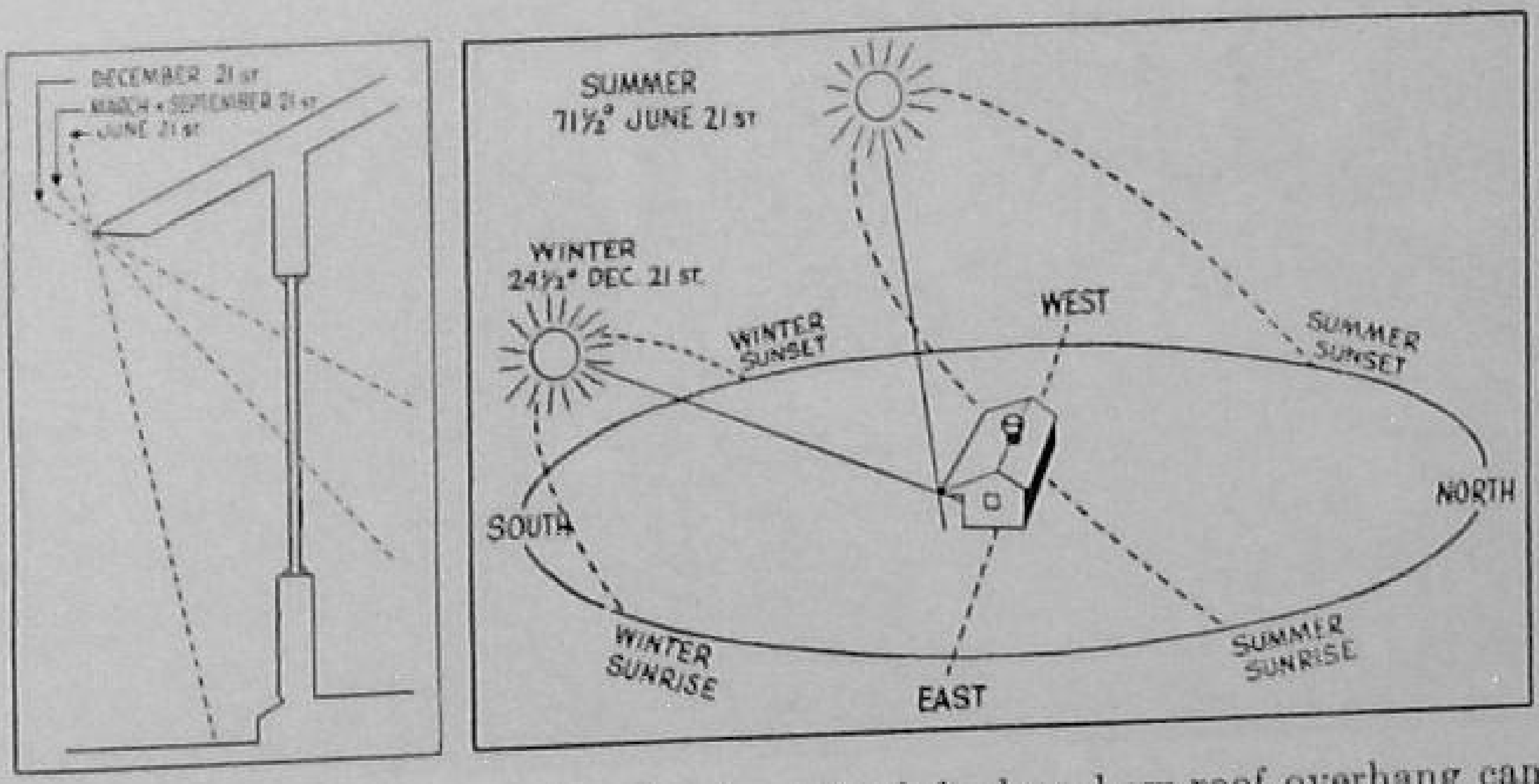


Fig. 114.—Dotted lines in the sketch at the left show how roof overhang can be used to shade out the sun's rays on June 21, yet permit them to strike the windows in winter. Diagram at the right shows the position of the sun at noon on June 21 and December 21 at Ames, Iowa. (*After Sprague and Eakin.*)

Trap Nests.—These differ from open nests in that each one is provided with a trap door by means of which a bird shuts herself in when she enters. They are the accepted means of securing accurate individual egg records and are an essential part of the equipment for pedigree breeding where more than one female is continuously mated with one male.

They are of many different styles. First in importance is their dependability as to accuracy, though it is hardly less important that they be comfortable and attractive, if floor eggs are to be avoided.

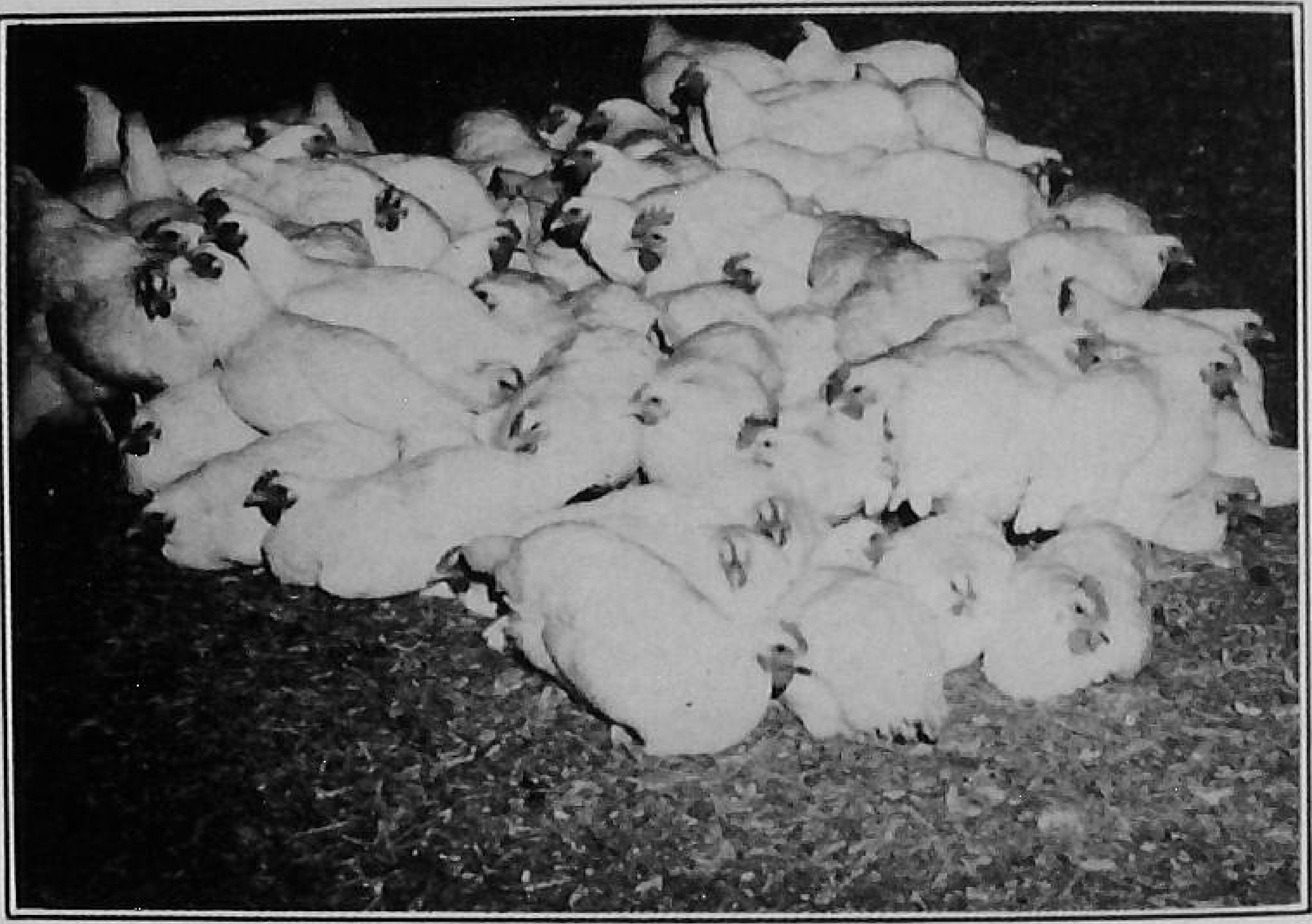


FIG. 119.—Some poultrymen are convinced that roosts are not necessary, especially for fowls of the heavier breeds. (*Courtesy of Poultry Tribune.*)

No trap nest is a comfortable place in extremely hot weather unless every effort has been made to have it abundantly ventilated. This may even require nest floors of hardware cloth and the discarding of the use of nest bedding for a time, allowing the birds to lay on the bare wire. There should be one trap nest for every 3 hens.

Perches.—The perches should be removable, free from cracks, located where there is no possibility of drafts, and comfortable. The roosting quarters are likely to be the part of the house most often infested with mites. Unless the perch is free from cracks and can be removed so as to expose the ends, it is very difficult to reach the mites and their eggs. Unless the eggs are reached and killed, spraying gives only temporary relief. In order to avoid drafts the perches should be located as far away from the windows or doors as possible. In an open-front pen this will usually be the back side.

In order to insure comfort the perches should allow from 8 to 10 inches of room for each bird and be 15 to 18 inches apart. Good rest is as essential to chickens as to any other class of livestock. The most common material used for perches is 2 by 3 or 2 by 4 inch lumber. This may be laid on the side or placed on edge. In either case it is well to round the upper edges.

With the rather general acceptance of built-up litter there has come a trend toward elimination of perches from houses used for laying hens as well as for broilers. This is especially true when flocks consist of the so-called heavy breeds—not Leghorns. This practice makes it unnecessary to install the usual droppings board.

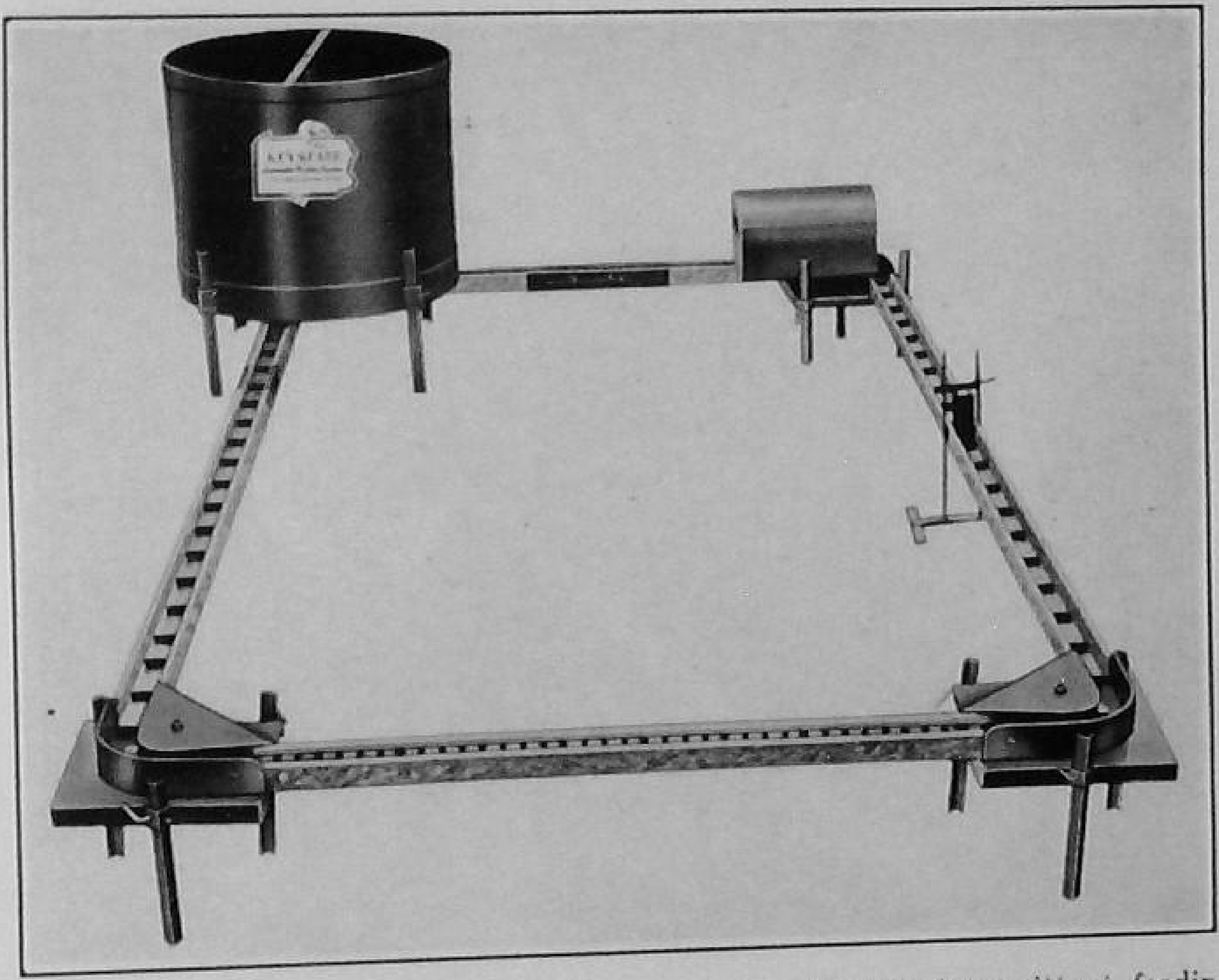


Fig. 120.—Mechanical poultry feeders provide automatic intermittent feeding. Capacity is about 8 layers or 20 broilers per lineal foot of trough. They are not considered economical for fewer than 400 hens or 1000 broilers. (*Courtesy of Keystate Manufacturing Company.*)

Droppings Boards.—The droppings board beneath the perches should be of the very best of matched material or of composition board so that hiding places for mites will be reduced to a minimum. It may well be removable so that the ends may be easily accessible when spraying. The droppings board should be far enough below the perches to provide sufficient clearance for easy cleaning.

Many poultrymen are adopting the practice of building the droppings board as a table or platform that is not attached to the wall. This is easily moved for cleaning and spraying, and during warm weather can be set out from the wall in order to provide a

maximum of air circulation about the hens while they are on the roosts.

Roosting Racks.—In order to eliminate the daily chore of cleaning droppings boards, many poultrymen have installed low roosting racks, or so-called droppings pits. The droppings accumulate on the floor, within a screened enclosure, and are removed only one to four times a year. Although there is a real saving in labor, the

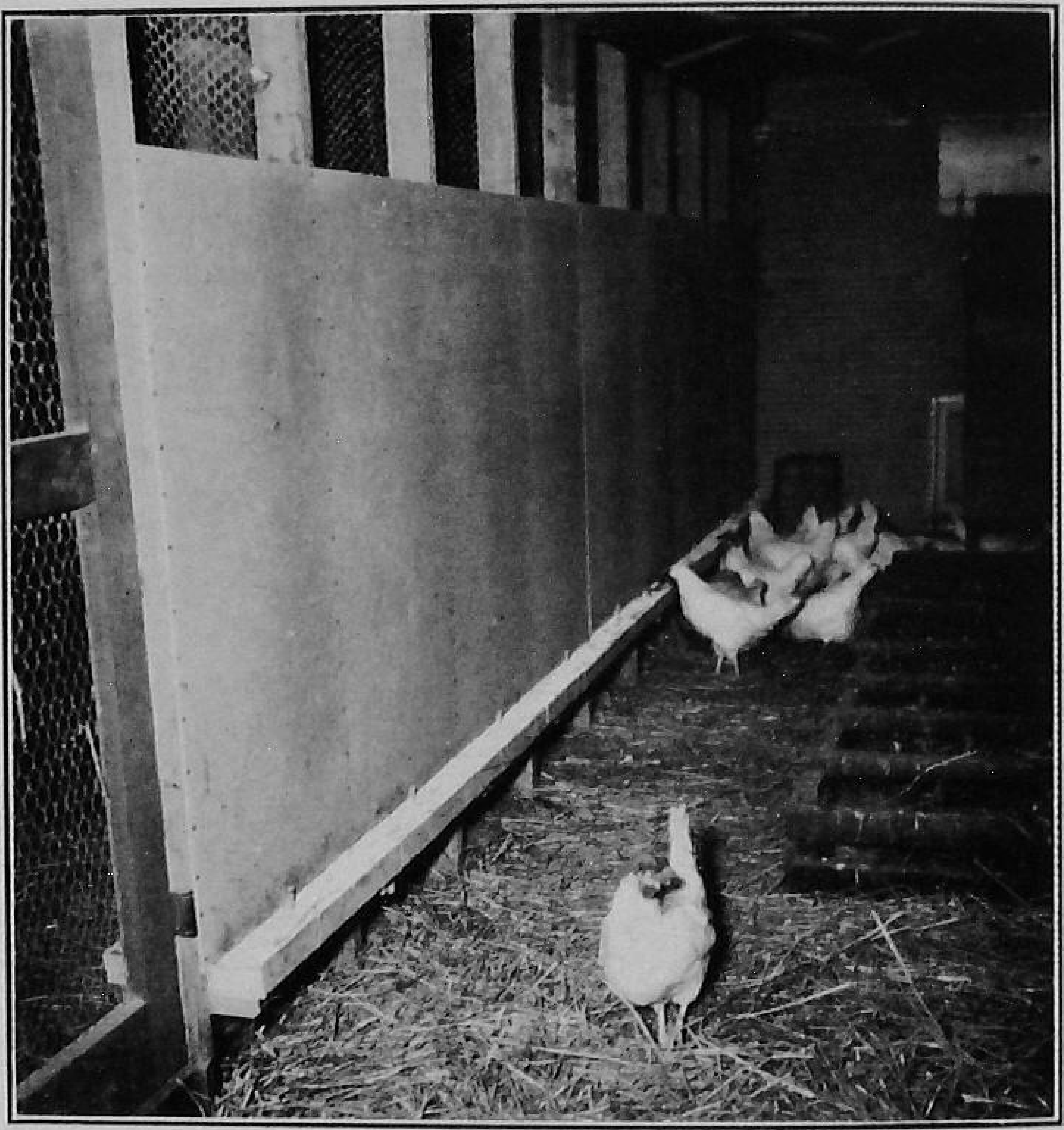


Fig. 121.—A simple type of oyster shell hopper built into a partition wall. It holds 1800 pounds of shell—enough to last 1000 hens about six months. (*Courtesy of Poultry Tribune.*)

racks are not a substitute for good management. There is danger of their becoming a haven for rats and mice and, unless some suitable fly repellent is used regularly, the accumulated droppings make an excellent breeding places for flies. This can be a serious handicap to adequate control of diseases and parasites. If the racks are built against a wall, it is difficult to prevent rotting of the lower part of the wall with consequent expensive repairs.

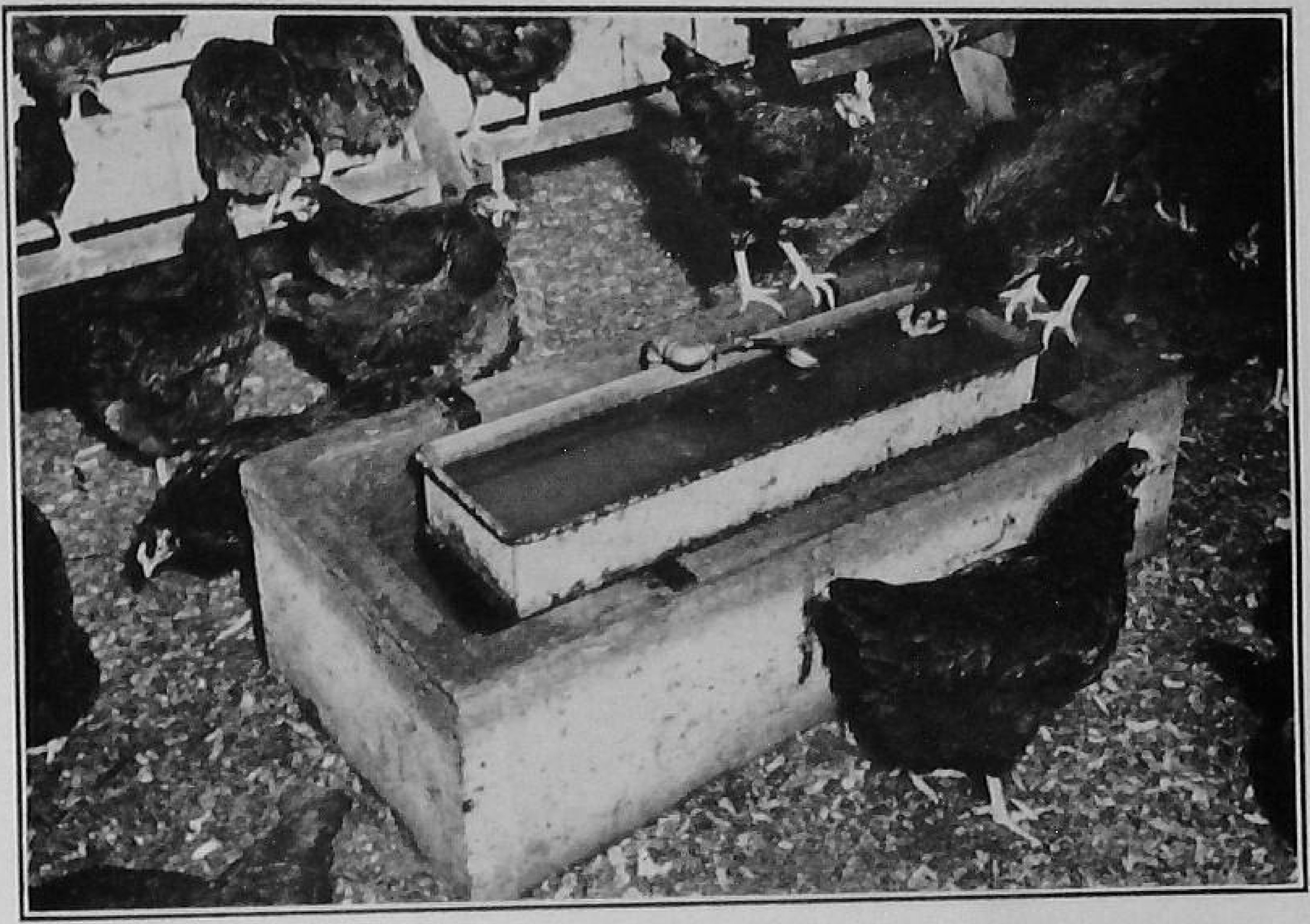


FIG. 122.—Overflow or drip from this trough type water fountain cannot cause wet litter. (*Courtesy of Minnesota Agricultural Experiment Station.*)

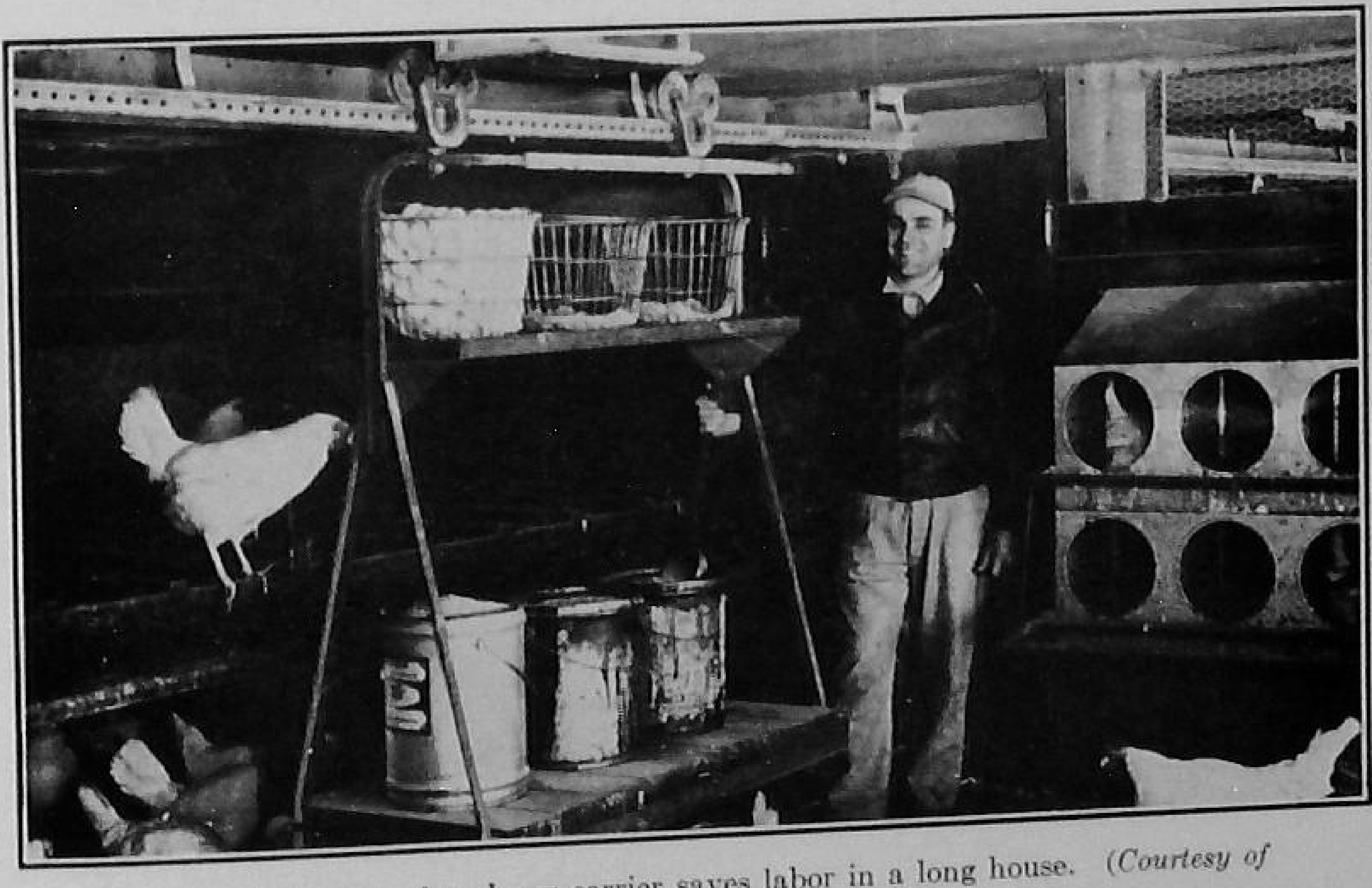


FIG. 123.—A feed and egg carrier saves labor in a long house. (*Courtesy of American Poultry Journal.*)

Broody Coop.—The broody coop is a great convenience for breaking up broody hens, isolating injured fowls, or for keeping extra male birds where one is alternating males. For its main purpose of breaking up broody hens it should be constructed with a slatted bottom. It is often convenient to locate the broody coop at the end of the droppings board, but it may be fastened to the wall or suspended from the roof.

Feeding Equipment.—The design of feeding equipment varies considerably on different farms and in different parts of the country. No matter what style of construction is used, the feeding devices should be easy to fill, easy to clean, built to avoid waste, so arranged that the fowls cannot roost on them, and constructed in such a manner that so long as they contain any feed at all the fowls will be able to reach it. From the standpoint of practical results it is essential that ample feeding space be provided. A safe rule to follow is to have 1 foot of hopper feeding space for every 5 hens.

Automatic or mechanical feeders have become popular in recent years. This is partly because they save a great deal of labor when they are working properly, partly because they can be adjusted for intermittent operation, with some resulting increase in total feed consumption, and partly because they appeal to many poultrymen simply as a mechanical gadget. They obviously are not economical for flocks of fewer than 400 hens, and they probably should not be used by anyone who does not have the necessary mechanical aptitude for keeping such equipment in working order. If something goes wrong with the automatic equipment, the chickens are very soon without feed, and there is no convenient way of turning back to hand feeding during the emergency.

Watering Devices.—A perfect watering device should keep the water clean and cool in warm weather, and be of such construction that it may be easily cleaned and that freezing will not destroy its usefulness. To keep water clean the watering equipment should be high enough so that litter will not be scratched into it, and so located that the fowls can not contaminate it with droppings.

In houses which lack sufficient insulation to prevent freezing, soil heating cable may be used to protect water pipes. A thermostat should be used to shut off the current at some pre-determined point, say 35° F., to prevent needless use of electric current. Proper installation, with suitable ground connections, is highly important from a safety standpoint.

Automatic watering devices are important from the standpoint of saving labor. Shallow V-shaped troughs running the entire length of the hen house and carrying a constant flow of water are very satisfactory for large flocks.

CHAPTER 8

THE PRINCIPLES OF POULTRY NUTRITION

THE primary reason for keeping hens is to accomplish the transformation of vegetable, animal and mineral matter in forms not usually eaten by man, into human food in the form of eggs and meat. In order to understand how to do this most efficiently it is necessary to know something of the food nutrients and their digestion and use by the fowl.

The objects of feeding are to furnish: (1) the proper kinds and amounts of materials necessary for the manufacture of bone, muscle, fat and the internal organs of the body; (2) energy and materials for the maintenance in perfect adjustment of the organs and tissues concerned in the body processes; and (3) the raw materials and energy for the elaboration of sperm and ova with their accessories.

The Maintenance of Life.—The first use of all feed is to support life. Unless life is maintained it is obvious that growth, reproduction, and gains in body weight cannot occur. The continuation of life and normal functioning of the animal organism depend upon (1) the maintenance of normal body temperature; (2) a certain minimum amount of muscular activity; (3) the renewal of tissues; (4) the periodic renewal of the feather coat; and (5) the elaboration of secretions.

In order for the various functions of the body, such as digestion, metabolism, fertilization and incubation, to be performed at their best it is necessary that there be maintained that degree of heat which is recognized as the normal temperature of the individual. For the common fowl this has been found to be about 107° F. This is several degrees higher than that maintained by man or by the common farm animals.

A considerable amount of muscular work must be done if the bird is to live. It must at least make the motions necessary for eating, and most individuals find it necessary to move about in search of feed. This is done of the fowl's own volition, and such movements are termed voluntary. At the same time there is considerable muscular activity within the body of the fowl over which it has no control, and which is termed involuntary. Such motion, for instance, is found in the beating of the heart and in the contractions of the gizzard and intestines. Energy must be furnished for both voluntary and involuntary motion, but the energy set free for such purposes is never completely used. Some of it is

wasted so far as motion is concerned, but may be used for the maintenance of body temperature.

Nitrogen and minerals are continually being lost from the tissues of the body and must be replaced. The exact nature of these processes has not as yet been entirely explained. From the practical viewpoint, however, it is perhaps sufficient to recognize the fact that the losses do occur and must be replaced.

There are numerous secretions that must be manufactured in the body of the fowl. Hormones, digestive enzymes, and mucus must be made. In order that the joints and muscles may move with little friction, and that the egg may slip down the oviduct to a successful expulsion, there must be secretions of the sort that may be referred to as lubricating material.

A certain part of the feed, therefore, must always be used for fuel, repairs and glandular secretions; that is to say, for the maintenance of life. The feed requirements for maintenance in domestic birds are about the same per unit of body surface area as for other farm animals. Per unit of body weight, however, the requirement is greater than for other farm animals because of the relatively small size of birds.

With hens in 50 per cent production, more than one-half of the food energy goes to meet the needs of maintenance alone and more than three-fourths of it is used for the combined purposes of maintenance and muscular activity.

Growth.—Growth is the direct result of a specific growth impulse in the young animal, and consists primarily of an increase in bone, protein tissue and water. Bone furnishes the framework for the support of the reproductive and vital organs and the attachment of the muscles. The protein tissue furnishes the material out of which the muscles and bodily organs are very largely fashioned. Muscle, which is termed lean meat when used for food, is one of the ultimate objects of poultry production, and often, as in the case of broiler production, is the primary object. The development of the vital organs is necessary to the maintenance of life itself.

Since every cell of the body contains protein, growth is possible only when protein is furnished in the food material in excess of the amount needed for maintenance. Similarly, certain of the tissues cannot be increased unless there is an ample supply of mineral matter.

Reproduction.—Not until growth is complete, or is nearing completion, can reproduction occur. Because the egg is so highly prized for human food as to have great commercial value, man has sought for many years to increase the laying ability of the domestic hen. As a result of continued selection, the reproductive season has been increased from a short period in the spring to a matter of several months. In the case of highly developed strains it has become an almost continuous process. The whole philosophy of

management and feeding for increased egg production is bound up in an effort to induce abundant reproduction. As with growth, reproduction can occur only when an excess of feed is furnished.

Fattening.—In all birds, and especially in those that have ceased to grow or reproduce, the feed consumed above that necessary for maintenance is either stored in the body as a reserve in the form of fat, or is dissipated as heat. The fact that certain individuals fatten readily while others, for the most part, merely transform excess food energy into heat has not as yet been completely explained.

THE NUTRIENTS

All feed ingredients are composed of one or more of the distinctly different groups of nutrients: (1) water, (2) minerals, (3) proteins, (4) carbohydrates, (5) fats, and (6) vitamins.

Of these, water alone is a definite chemical compound. Minerals, proteins, carbohydrates, fats and vitamins, which collectively form the dry matter, are classes or groups of compounds, each group having certain distinctive characteristics. Compounds of similar physical or chemical composition are placed within each group for convenience.

Both the fowl's body and the egg are composed of the same six groups of food substances. These are not, in most cases, transferred directly as such from the feed to the tissues, but are split up in the digestive tract, absorbed and rebuilt in the body.

There is, however, a close relation between the composition of the feed and its use in building tissue. The minerals in the body or in the egg can come only from the minerals in the feed. The protein of the body can not be built up nor the protein of the egg formed except when nitrogen carriers of the proper kinds are furnished from the outside. While fat may be manufactured from protein, it is normally built up from carbohydrates or made over from fats in the feed. The very small amount of carbohydrates in the fowl's body and the still smaller amount in the egg usually have the carbohydrates of the feed as their original source, but may also come from the proteins. The source of vitamins in the body of the fowl is the vitamins or provitamins of the feed, except as they may be supplemented by those which can be synthesized by the chicken or by organisms in its digestive tract.

Water.—Water plays a highly important part in the digestion and metabolism of the fowl. (1) It is a constituent part of the body and of the contents of the egg, comprising from 55 to 75 per cent of the former and more than 65 per cent of the latter; (2) it serves to soften the feed in the crop, preparing it for maceration in the gizzard; (3) it aids and takes a part (hydrolysis) in the processes of digestion and absorption; (4) as an important constituent of the blood and lymph it serves as a carrier, transporting the end-products

It is sufficient to see that the critical amino acids are furnished in ample amounts, and that the total protein is high enough to enable the chicken to synthesize the necessary amounts of some 15 others which are non-critical. There are, however, certain interrelationships, not only among amino acids but between amino acids and vitamins, which must be taken into account.

Methionine can furnish part of the materials needed by the chicken for synthesizing the other sulphur-containing amino acid, cystine. If there is enough methionine present, cystine is not necessary, but surplus cystine will not replace methionine. In practice, it is both difficult and expensive to provide excess methionine, to say nothing of the nitrogen wastage involved in the conversion. It is therefore customary to provide a minimum of methionine and also a minimum amount of the two together. Similarly, tyrosine can be synthesized from excess phenylalanine, but is dispensable only when there is enough phenylalanine in the ration to meet the needs for both of these amino acids.

Another amino acid, tryptophane, can be used by the chicken to form niacin, one of the water-soluble vitamins. Here again, it is more practical to provide ample amounts of niacin than to depend upon the limited amounts of tryptophane present in most feeds. Similarly, methionine is an important methylating agent and can, if necessary, take the place of part of the choline (another water-soluble vitamin).

There is abundant evidence also that many of the vitamins are necessary for the retention and full utilization of the amino acids.

Carbohydrates.—Carbohydrates are compounds of carbon, hydrogen and oxygen in which the hydrogen and oxygen are almost always in the same mutual proportion as in water (H_2O). They are plentiful in plants, appearing usually in the form of sugars, starches, pentosans or cellulose. As protein predominates in the fowl's body, so carbohydrates predominate in the structure of the plant.

Starch is the form in which most plants store their reserve energy. The starches stored in the kernel of corn and the potato tuber are familiar examples.

The skeleton or framework of plants consists mostly of cellulose. In feeds it is called crude fiber, and it is actually a disadvantage in the formulation of rations for young chicks. Common seeds and grains vary from 2 to 11 per cent in their content of crude fiber.

Carbohydrates are important and valuable in poultry feeding because they furnish the chief source of energy for the growing chick or laying hen.

Fats.—In this group of nutrients are included not only the true fats but also certain fat-like substances such as cholesterol, ergosterol, waxes and lecithins. The true fats are organic compounds of carbon, hydrogen and oxygen, but they contain these elements in very different proportions than do the carbohydrates. Perhaps

the most characteristic difference is that the fats contain a much lower percentage of oxygen. It is because of this and their higher content of hydrogen that the fats have such a high calorific value.

Certain fats, like tallow, are quite firm and hard because they contain rather large percentages of the higher molecular weight and saturated fatty acids. Others, like chicken fat, are quite oily because they contain considerable percentages of the lower molecular weight, and unsaturated fatty acids.

Fats (lipins) are present in all cereal grains, but in very small proportions as compared with the body of the fowl or even the egg. While they form less than 5 per cent of the air-dry weight of corn and oats, and less than 2 per cent of wheat, they constitute nearly 20 per cent of the live weight, and about 45 per cent of the dry-matter weight, of a 4-pound Leghorn pullet. Fat comprises 9.3 per cent of the weight of the new-laid egg, all but a trace being located in the yolk, of which it forms 33.3 per cent.

Fat is the reserve material of the animal body. The percentage of fat seldom falls below 6 in the very lean animal, while it may rise as high as 40 in the very fat animal. It serves as a store of energy to be drawn upon as the need arises. Since fat is a non-conductor of heat, the subcutaneous deposits constitute a very efficient protection against cold. This is more important in large animals than in poultry.

Fat-Soluble Vitamins.—Perhaps the most significant fact about vitamins as a group is that, although they are absolutely essential to the normal functioning of the animal body in certain respects, most of them are needed in but minute amounts in comparison with the other nutrients. It is worth noting that eggs, when laid by hens fed on rations which are nutritionally adequate, are prominent among the excellent animal sources of vitamins. No other substance except milk is so important a carrier of so many of the vitamins.

Although most of the known vitamins are unrelated chemically, they may conveniently be classified as fat-soluble and water-soluble. The first group includes vitamins A, D, E and K. All the rest are water-soluble. The functions of the individual vitamins in poultry nutrition will be indicated briefly in the following paragraphs, together with symptoms of deficiency. The requirements for those which need to be considered in the formulation of rations will be given in Chapter 10.

Vitamin A.—All animals, so far as known, require some dietary source of vitamin A or one of its precursors. Its function is closely related to the proper nourishment of epithelial tissues. In this way it helps to protect the chicken against various bacterial infections. Deficiency symptoms include deposits of urates in the ureters and kidneys, general unthriftiness, lessened egg production and, in extreme cases, nutritional roup. Potent sources are fish liver oils.

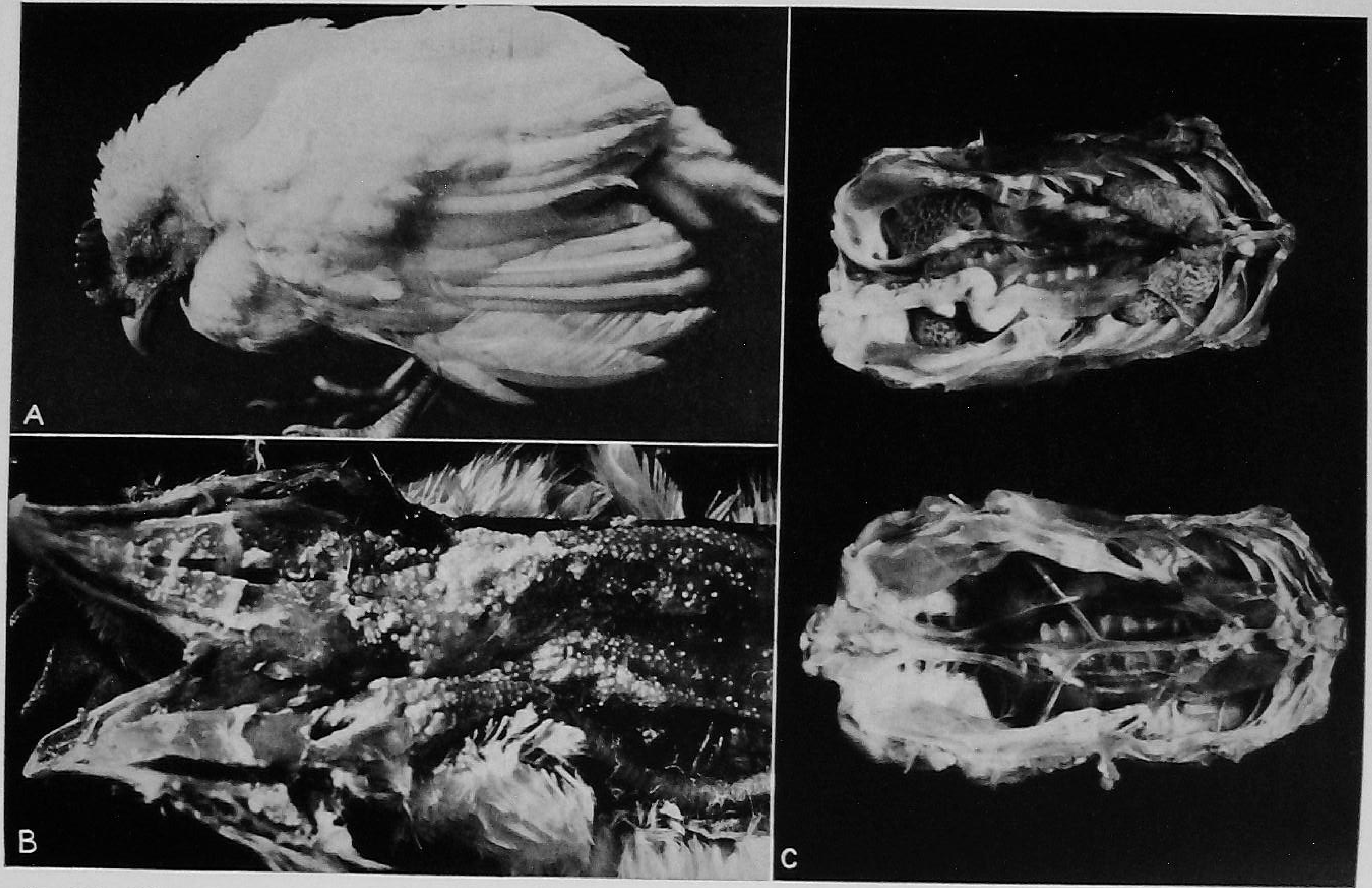


FIG. 125.—Effects of vitamin A deficiency. *A*, An advanced stage. Note the exudate from the eye and the general ruffled appearance. *B*, The pharynx and esophagus are studded with pustules. *C*, Whitish ureate deposits in the kidneys and the enlarged ureter of the upper specimen are compared with the normal condition below. (*Courtesy of the National Research Council*).

and vitamin A and D feeding oils. Chickens, like other animals, are able to transform the carotenes of plant tissues (fresh green forage, alfalfa meal, and the like) into vitamin A. They can also make similar use of the pigment cryptoxanthin in yellow corn.

Vitamin D.—The primary function of vitamin D is to promote normal absorption, deposition, and retention of calcium and phosphorus in the young animal. If this vitamin is deficient or absent, young chicks will soon develop rickets, a condition in which the growing bones fail to calcify normally. The chicks are not only unthrifty, and retarded in growth, but they become lame and show a disinclination to walk.

The most important function of vitamin D in mature fowls is concerned with reproduction. Under conditions of vitamin D deficiency the shells of eggs being laid by hens on such a diet become progressively thinner until production finally ceases. Long before these conditions are apparent, however, there will be an unfavorable effect on the eggs from the standpoint of embryo development and hatching power. The low hatching power of eggs produced by hens fed a ration which is deficient in vitamin D is probably related to the low power of the developing embryos to transfer lime from the shell.

The ultra-violet rays in sunlight and in the light from quartz mercury vapor lamps have the power to serve the same practical function as vitamin D in relation to calcium and phosphorus metabolism. What happens is that one or more of the sterols present in the skin, when exposed to the action of ultra-violet irradiation and absorbed by the body, will be changed to vitamin D.

Not over 0.1 per cent of the sun's radiant energy in many parts of the country has anti-rachitic value, but even this small amount need not be available to chicks for more than ten minutes daily in order to afford protection against rickets if the chicks are fed an otherwise complete ration which lacks the anti-rachitic factor.

The chemical nature of vitamin D is much more complicated than was thought a few years ago. It is known to occur in several different forms, and these are of varying potency for different species of animals. The most potent practical sources are fortified fish liver oils, vitamin A and D feeding oils, and irradiated animal sterols.

It must be emphasized that vitamin D is not a substitute for the minerals required in bone formation. Calcium and phosphorus must be present in the proper amounts and in the right ratio. Vitamin D merely enables the body to make use of these substances in bone formation.

It has been amply demonstrated that the antirachitic potency of egg yolks can be greatly increased by irradiation of the hens or by the feeding of substances rich in vitamin D.

DIGESTION

Digestion is the process, accomplished by the alimentary system, of so dissolving and chemically changing the material taken into the alimentary canal that it can be absorbed by the blood and used by the body.

The Digestive Process and Assimilation.—The nutrients of the feed must undergo certain changes before they can be absorbed and used by the body. Something is known concerning these changes in regard to the proteins, carbohydrates and fat. Nothing is known regarding the changes, if any, in the case of the vitamins, and very little regarding the minerals.

Mechanical Processes.—The mechanical processes involved in digestion, some of which have been mentioned in discussing parts of the alimentary tract, include prehension of food, mechanical disintegration of the food, intimate mixing of the resulting particles with the digestive enzymes, exposure of the final products to a large absorptive surface, propelling of the food along the alimentary tract, and discharge of the digestive residues and other excretory products. All but the first and last of these processes are accomplished by smooth or involuntary muscles.

Enzymes and Enzyme Action.—The importance of enzymes in digestion is clear when it is realized that the changes in nutrients that take place in the animal body are brought about at ordinary temperatures, and in nearly neutral solutions that are extremely dilute. To hydrolyze proteins in the laboratory requires twenty-four to sixty hours of constant boiling with strong acids, and yet the digestive enzymes accomplish it easily in a very short time. The chemist cannot make fat from sugar in the laboratory, but the body does it easily.

The action of these digestive enzymes is chiefly hydrolytic. Very little heat is liberated by their action, hence little energy is lost by the animal. Certain *exogenous* enzymes, bacteria, yeasts and molds taken in with the food play a part in digestion. They cause a wide variety of reactions, in many of which there is loss of energy unless the body is in an environment such that it can make use of the heat liberated.

Proteins.—Feed proteins as such cannot be made use of by the cells of the body. In fact, if injected directly into the blood stream, they act as poisons. They have to be broken down into amino acids which can pass through the membranes of the intestine and be absorbed by the blood. The blood distributes the amino acids to all parts of the body where they are used for the construction of body tissues and their products.

Carbohydrates.—The starches and even the sugars, such as maltose, cannot pass through the intestinal membranes until they

have been broken down into simple sugars referred to as the monosaccharides.

Carbohydrate digestion in the fowl consists chiefly in the hydrolysis of starch to maltose, and then to glucose, which is absorbed rapidly from the intestine. Glucose, fructose and galactose are the only monosaccharides to get into the liver through the portal system, and glucose is the only carbohydrate of the blood stream.

Fats.—The processes involved in fat absorption are still a subject of controversy among physiologists. Current theories suggest that it is not necessary for fats to be hydrolyzed before they can be absorbed. Whatever the process or processes involved in absorption, the fats found in the capillaries and in the lymphatic system are neutral fats. In the fowl it seems clear that a large part of the fatty acids of a high fat meal are absorbed by way of the portal system, rather than by way of the lymphatic system.

The fats of the lymphatic system approximate the composition of body fat much more nearly than do the ingested fats. The body does the best that it can to transform the ingested fats into fats that are characteristic of the species. Furthermore, for any given animal, the fat formed from excess carbohydrates is always the same.

The fat toleration of birds, in common with herbivora, is not very high. Although, as a source of energy, fats are worth two and one-quarter times as much as protein or carbohydrates, fat concentrates are not used in ordinary feeding practice, dependence being placed on carbohydrates, even for fattening purposes.

Crude Fiber.—Food materials used in poultry feeding nearly all contain some crude fiber. As determined in the laboratory, this consists of cellulose, lignin, cutin and some pentosans. In the ruminant some of this material is broken down by the action of exogenous enzymes taken in with the food, as well as by bacterial action. With fowls, however, bacteria have little opportunity for action. As soon as the hard-coated grains become moist and soft enough for bacteria to work upon them, their chemical reaction is already acid. Very soon after passing from the gizzard to the intestine they are mixed with the bile, which inhibits bacterial development. The rectum is so short that there is no appreciable amount of bacterial action possible there. This leaves the ceca as the only place in which bacteria have an opportunity for effective action.

Because of the short time required for feeds to pass through the digestive tract of the fowl, very little digestion of crude fiber can occur even in the ceca. It has been shown that the ceca slowly fill with the fluid contents of the intestine, and then empty themselves at intervals ranging from eight to twenty-four hours, depending upon the nature of the food consumed. This would suggest ample time for bacterial action, but the amount of food material

The sources of stored fat in the body are: (1) ingested fats which, after digestion and absorption, are found in a form that is more nearly like body fat than they were when eaten; and (2) carbohydrates that are used in the manner already described. The fat formed from carbohydrates is, for a given species, always the same. That formed from ingested fats is dependent to some extent on the character and amount of the ingested fat. The fact that the body is limited in its ability to transform ingested fats explains why, for example, the feeding of certain forms of fat to swine results in soft pork.

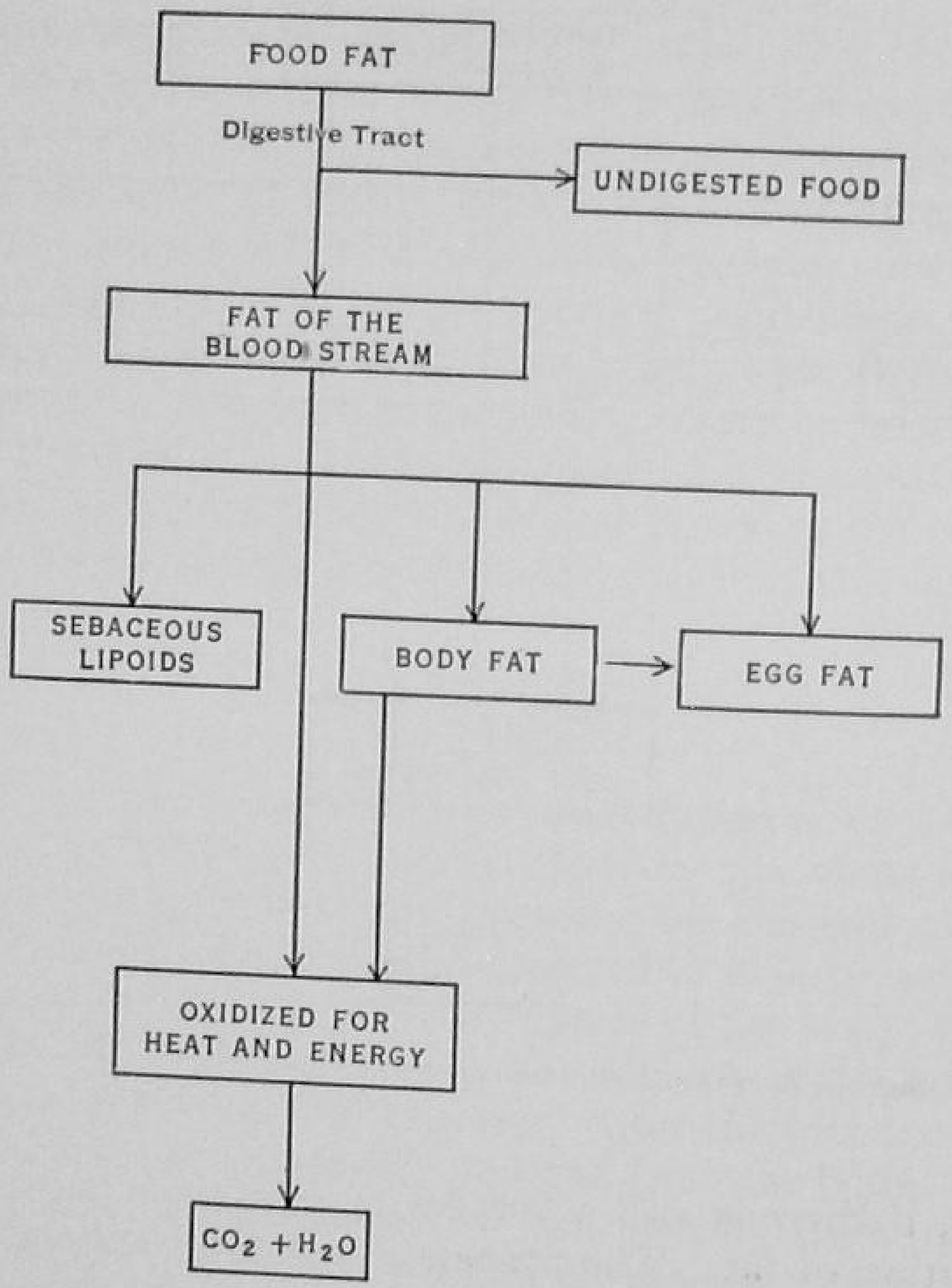


FIG. 130.—Diagram showing the normal uses which the body makes of fats.

Fat once absorbed from the intestine is never excreted, except for the small amount of sebaceous lipoids in the skin. There is no physiological limit to the storage of fat, but there is a very definite limit to the storage of carbohydrate as glycogen. When the glycogen stores are at a maximum, the excess carbohydrates are stored in the form of fat, as has already been explained. The important uses that the body makes of fats are indicated diagrammatically in Figure 130.

Protein Metabolism.—Proteins are not stored in the sense that the other nutrients are. Their chief function is structural, though an excess above the structural needs can be used for energy. Because of price, they are not so economically used for this purpose as are the carbohydrates, and hence, in practical feeding operations, it is usually desirable to reduce the level of feeding of the more costly protein feeds to a reasonable minimum as indicated by the requirements of the animals being fed.

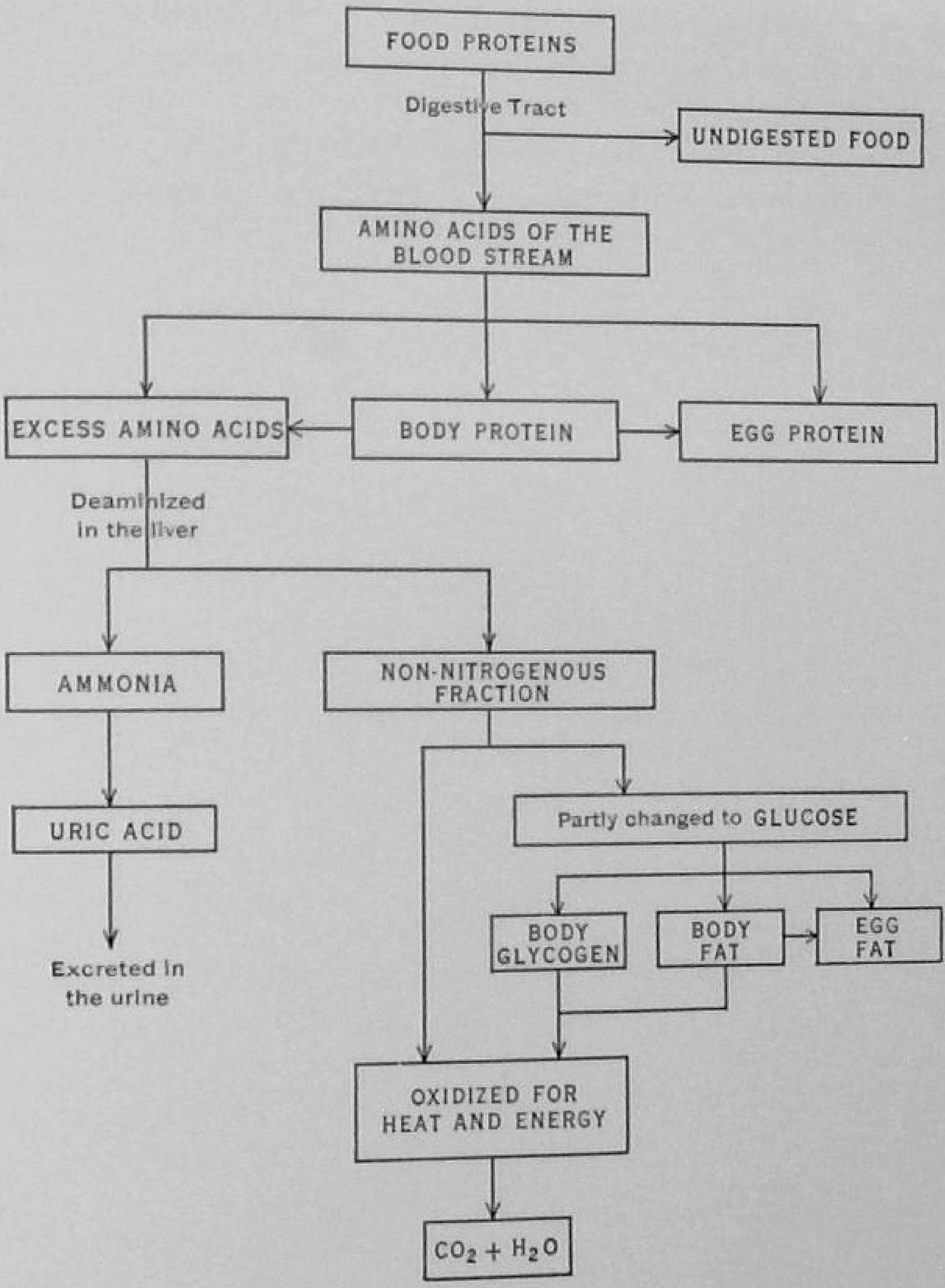


FIG. 131.—Diagram showing the normal uses which the body makes of proteins

Before the excess amino acids can be used for other than structural purposes they must be deaminized. The nitrogen that is thus split off is excreted by way of the kidneys, chiefly in the form of uric acid. The non-nitrogenous portion may be oxidized immediately to CO_2 and H_2O, or part of it may be stored in the form of glycogen or fat, if conditions make that necessary. The important

Rye is ordinarily considered unsuitable for use in poultry rations, because it is less palatable than other grains and causes sticky droppings when fed at high levels. Tests at the Wyoming Station showed, however, that it can be fed to laying hens in quantities approximating two-thirds of the entire ration without any serious effect on egg production. It was also found practical in chick rations up to a maximum of 20 per cent.

In feeding trials at the Wisconsin Station, chicks that were fed a diet in which 15 per cent of bran and 15 per cent of middlings were replaced by ground rye, grew slowly, and at twenty weeks of age weighed only three-fourths as much as those grown on the control ration. The droppings of the rye-fed chicks contained a pasty material which clung to the toes of the chicks, forming large round balls. The material had to be removed at frequent intervals in order to permit the chicks to exercise and eat.

PROTEIN SUPPLEMENTS

Since all grains and grain by-products are deficient in both amount and quality of protein, it is necessary to supplement them with suitable proteins from other sources. The common ingredients for this purpose are the oilseed meals and certain animal protein concentrates. The relative importance of the various high-protein feeds is shown by the following figures for total consumption by all livestock, excluding work animals, for the year beginning October 1, 1949.

	1,000 Tons
Soybean cake and meal	4,514
Cottonseed cake and meal	2,375
Corn gluten feed and meal	926
Tankage and meat scrap	842
Linseed cake and meal	670
Fish meal	261
Dried milk products	100
Peanut cake and meal	93

Protein concentrates of animal origin have long been favored by poultrymen because of their special value in supplementing the cereal grains. With increased knowledge about amino acid and vitamin requirements, this distinction is no longer important. It is not a question of whether an animal protein or a plant protein is in itself a "good" protein, but whether the combination of proteins to be fed is adequate in its amino acid makeup.

Animal protein supplements often contain other nutrients, *e.g.*, phosphorus, choline, riboflavin, vitamin B_{12}, in which the cereal grains are deficient.

Whether plant protein supplements should be used in part to replace animal protein supplements, will depend partly upon the relative prices of the two. A good rule to follow in practice is to

see that at least one-fourth of the protein supplement used is of animal origin.

Animal Protein Supplements.—The animal protein supplements commonly used in poultry feeding include milk and its products. packing-house by-products, and by-products of the fishing industry,

Fish Meal.—Fish meal has been used for many years in the feeding of poultry. Menhaden fish meal, made from the menhaden herring, accounts for about half the total production. Most meals today are made by the vacuum drying process and hence are of better quality than meals made by the former flame-drying process which exposed the product to high temperatures. The better grades of fish meal are excellent sources of protein for poultry, but the total tonnage available is far short of what the industry could use.

Fish Solubles.—Condensed fish solubles, made by evaporating the watery material pressed out of fish waste along with the oil, is valuable both as a protein and a vitamin concentrate for poultry. It is usually dried to a 50 per cent solids content so that it contains about 30 per cent of protein. It is a good source of riboflavin, niacin, pantothenic acid and choline.

Insects.—When on range, birds will often eat large numbers of insects. Occasionally, as during grasshopper plagues, quantities of insects are captured, dried and used for poultry feed. Dried grasshoppers contain about 75 per cent protein, 7 per cent fat and nearly 6 per cent minerals.

Tests at the Oklahoma Station showed, however, that dried grasshoppers were not suitable as a protein supplement in rations for growing turkeys. The greater the percentage of dried grasshoppers fed, the slower was the growth, and the higher was the mortality.

Meat Scrap.—Meat scrap is composed of the material remaining after partially extracting the fats and oils from animal tissues. Most meat scrap carries a minimum guaranteed content of 50 per cent protein. If it contains more than 10 per cent of phosphoric acid it must be sold as meat and bone scrap.

Because of variation in the types of materials that go into meat scrap, or other meat products of similar nature, it is possible for two samples of a given product to have very similar composition as determined by routine analysis, and yet have quite different feeding values. If made almost entirely from adipose tissues, the nutritive value would be much less than if it were made largely from trimmings of lean meat.

Meat scrap is probably the most widely used of all animal protein supplements, though in certain localities it is almost entirely displaced by fish meal or milk.

Milk Products.—Whole milk is seldom available as a poultry feed because of the high value of butter fat. Both skim milk and buttermilk are extensively fed, in liquid, condensed, and dried form.

When protein alone is considered, a choice of one form of milk over another can be justified only on the basis of cost, availability of the product or convenience in feeding. In other words, there is nothing to indicate a difference in feeding value of a pound of protein in dried milk as compared with a pound of milk protein in some other form. From a quantitative standpoint, 1 pound of dried milk is equivalent to about 3 pounds of condensed; and 1 pound of condensed is equivalent to about 3 pounds of liquid milk; hence 1 pound of dried milk is equivalent to 9 or 10 pounds of liquid milk.

The proteins of milk are almost completely digestible, and they are of special value in supplementing the proteins in cereal grains and their by-products.

It is often claimed that sour milk is of greater feeding value than sweet milk, but extensive feeding trials in which the two have been compared have failed to show any superiority of one product over the other. Furthermore, chicks have been fed both sweet and sour skim milk each day during the first eight weeks without any harmful results.

Milk in its various forms is especially valuable as a constituent of the ration of young chicks, and of hens from which eggs are being saved for hatching purposes. This is probably due, in part, to the fact that the presence of lactose favors the assimilation of calcium, as well as to the riboflavin which milk contains.

Tankage.—Tankage is a finely-ground product made from the residues from animal tissues as obtained in packing plants. Different tankages may consist of the products obtained by either the wet process or the dry-rendering process, or a mixture of these products, to which blood and stick may be added. Meat scraps, on the other hand, must consist only of dry-rendered residues to which no blood or stick has been added.

Tankages may be sold as digester tankage, meat meal digester tankage, meat meal tankage, or feeding tankage. If they contain more bone than that equivalent to 22 per cent of tri-calcium phosphate the word "Bone" must also be included in the brand name. The same type of variations mentioned in regard to meat scrap apply to tankage.

Though meat scrap is much more commonly used for poultry feeding than is tankage, it would appear that a good grade of tankage may be better than a poor grade of meat scrap. The weight of opinion based on poultry practice is in favor of meat scrap, but investigational work has not demonstrated any great difference between them.

Plant Protein Supplements.—The plant protein supplements available for poultry feeding are obtained chiefly from certain of the oil-bearing seeds such as cottonseed, flaxseed, peanuts, and soybeans. Brewers' grains and distillers' dried grains are also used to a limited extent.

Cottonseed Meal.—Properly processed cottonseed meal is a valuable protein concentrate for poultry feeding. Unless the pigment glands are removed during processing, or the gossypol which they contain is inactivated, the meal is not satisfactory for use in chick rations. Fortunately, the industry is making rapid progress in the matter of processing so that this valuable ingredient can be more widely used in poultry rations.

Since cottonseed meal is relatively low in lysine, it should not be used as the only protein supplement in a ration. Small amounts of blood meal or fish meal will correct the deficiency.

Several investigators have noted the unfavorable effect of cottonseed meal on the storage quality of eggs, specifically the development of "cottonseed spots," and have indicated that deterioration begins as soon as four weeks after the eggs are placed in storage. The condition is not observed in the eggs when first laid.

The characteristic discoloration of yolks in eggs laid by hens fed cottonseed meal can be made to occur in a matter of minutes by placing the yolks in an atmosphere of ammonia. Iron is released from the yolk proteins, and combines with gossypol from the cottonseed meal to cause the discoloration.

If certain iron salts, such as ferric chloride or ferrous sulphate, are fed along with the cottonseed meal, they combine with the gossypol and prevent its absorption from the intestinal tract. About 0.5 per cent of the iron salt seems to be needed. Without this precaution, no more than 5 per cent of cottonseed meal may safely be fed to laying hens if yolk discoloration is to be avoided.

Linseed Meal.—In the extraction of linseed oil from flaxseed, the residue or cake is ground to make the linseed meal used in livestock feeding. Since the meal is laxative, and contains a substance which is toxic to chicks, it is not widely used in poultry feeding. The toxic material can be inactivated or destroyed by a simple treatment which consists in letting the meal stand for 18 hours at about 100° F. after being mixed with about twice its weight of water.

Peanut Meal.—This is a by-product of the manufacture of peanut oil. It is not extensively used in poultry feeding.

Soybean Oil Meal.—This popular protein concentrate is made by crushing, cooking, and removing most of the oil from soybeans. It is a valuable protein feed and has come to be used more widely than any other such ingredient. It is sold under labeling which indicates the protein content and the method of manufacture. The common expeller method is rapidly being replaced by solvent processes, largely because it is possible to remove more of the oil by the use of solvents. Solvent extracted meal contains about 45 per cent of protein and 0.5 per cent of fat.

Like other plant protein feeds, it is deficient in minerals when compared with such animal protein feeds as meat scrap. It is also low in methionine.

poultry. The usual procedure is to specify minimum levels of the various nutrients which are needed in a ration to be used for a particular purpose. The level may be expressed as the percentage of protein in the total ration, the number of milligrams of a particular vitamin in each pound of feed, or the parts per million of some trace mineral. In any case, the recommendation must be based on a knowledge of the minimum nutritive requirements. The requirements for maintenance, for growth and for egg production will therefore be discussed separately in the following sections.

A very considerable part of the ration of laying hens is used for maintenance purposes, and this part of the cost of keeping them goes on day by day throughout the year, whether they are laying well or poorly or not at all. Hence the maintenance requirement is of practical as well as theoretical interest. It includes the requirements for both basal metabolism and normal activity. The combination is sometimes referred to as "economic maintenance."

By basal metabolism is meant the basal heat production, or the minimum energy expenditure of the individual. It is the heat production which occurs under conditions such that the influences of feed, of environmental temperature and of voluntary activity are removed. It results in a continuous demand for food energy and appears to be, for a given animal, one of the most constant of biological measurements.

Energy Requirements for Maintenance.—The amount of energy required for "economic maintenance" is affected by a number of different environmental factors, as well as by certain conditions which are inherent in the individual animal, such as size, age, sex, environmental temperature, and the degree of activity.

It is well known that basal heat production per unit of body weight varies with the size of the animal. The minimum heat production of day-old chicks, for example, is about 5.5 small calories per gram of live weight per hour, twice as much as the corresponding figure for adult hens.

The basal metabolic rate of males is usually higher than that of females by about 5 to 7 per cent. Castration lowers the basal heat production by as much as 13 per cent in 9-month-old-capons.

Effect of Temperature.—Because of the ability of warm-blooded animals to maintain a constant body temperature that is normally several degrees above the environmental temperature, the animal is constantly losing heat to its surroundings. This loss of heat means a loss of energy that must be supplied in the feed. Heat production must equal heat loss if the animal is to maintain its normal temperature, and this means that there is a rapid increase in the metabolic rate whenever the environmental temperature falls below the critical point. Unless sufficient excess energy for this purpose is liberated by increased voluntary or involuntary activity, additional food or stored energy must be oxidized.

The minimum rate of heat production in day-old chicks occurs in an environmental temperature of 95° F. Heat output is more than doubled at a temperature of 75° in order to compensate for increased heat loss. For the adult hen, the minimum basal heat production occurs over a range of about 10 degrees between 65° and 75° F. These values are for fasting chickens at rest.

Effect of Feeding.—Feeding an animal will increase its heat production, and the higher the level of feeding, the greater will be the heating effect. A flock of hens on full feed will be better able to withstand the effects of cold weather than will a flock which is for any reason on reduced rations. Liberal feeding of the energy-carrying feeds in cold weather is a thoroughly practical procedure for which there is a definite scientific basis.

Effect of Normal Activity.—It has often been suggested that the energy requirement of normally active fowls is about 50 per cent greater than the basal energy requirement. This is probably correct for either chicks or hens running at large, but it is too high for chicks grown to market weight indoors, as is common in broiler production, or for laying hens kept either in cages or on the restricted floor areas which are common in commercial practice today. In the various discussions in this book which make necessary an allowance for the increased heat production due to voluntary activity an increase of one-third over the basal requirement is assumed.

Protein Requirements for Maintenance.—The basal or minimal requirement for protein will be that resulting from the endogenous protein catabolism. It is measured by the amount of nitrogen in the urine of an animal that is fed a nitrogen-free diet so designed as to furnish all other nutrients in ample amounts. This requirement for nitrogen to cover the endogenous loss is often expressed in terms of milligrams per kilogram of body weight. It has been shown by Smuts, working at the Illinois Station, that for rats, mice, guinea-pigs, rabbits and swine, the endogenous nitrogen amounts to 2 mg. per Calorie[1] of basal heat production. This study was based on mature animals of each species, and it seems reasonable to suppose that the relationship might hold equally well for chickens.

The nitrogen requirement of young chickens is greater per unit of weight than that of older fowls. This is in line with the constant relationship to surface area found by Smuts, and means that the young animal has an exaggerated endogenous loss. As to the effect of sex, there is no information, though it seems reasonable to assume that the requirement per unit of weight will be higher in males than in females because of the higher basal metabolic rate of males. Generally speaking, no other factors affect the endogenous nitrogen loss under normal conditions. Hence the simplest method of estimat-

[1] Unless otherwise stated, the term Calorie as used in this discussion means the large or kilogram calorie. It is the amount of heat required to raise the temperature of 1 kilogram of water by 1 degree Centigrade.

ing the basal nitrogen requirement is to apply Smuts' factor to the calculated basal heat production.

All available evidence indicates that muscular activity does not in any way affect the protein requirement, provided there is furnished an ample supply of food energy for the energy requirement of the activity.

Mineral Requirements for Maintenance.—The mineral requirements are more difficult to determine and evaluate, and but little definite information is available. There will be mineral losses under maintenance conditions, but the nature of mineral metabolism is such that in both the growing chick and the laying hen these losses are greatly overshadowed by the specific requirements for growth and egg production. Indirect evidence suggests a minimum requirement of 2 grams of calcium for each 100 grams of net protein. In terms of minerals fed, this amount would have to be doubled, as it has been shown by the use of radioactive Ca^{45} and P^{32} that only about half of the calcium and phosphorus fed is retained by the laying hen.

The other mineral requirements, like the vitamin requirements for maintenance, have little practical significance and are therefore not considered here.

THE REQUIREMENTS FOR GROWTH

When the maintenance requirements have been met, the chicken is in a position to make use of any surplus nutrients for other purposes, such as growth or egg production. So far as growth is concerned, the nutritive needs will be the specific requirements for the elaboration of the new tissues that make up the changes in weight, form or chemical composition. Because of wastage in digestion and metabolism, the actual feed requirements are much greater, as will be indicated in the following paragraphs.

There is some reason to think that the best ration or formula for rapid growth to a weight of three, four or five pounds is not necessarily the best ration in terms of maximum feed conversion, and that the ration which produces the best market finish may be somewhat different from either of the other two. Current research may be expected to provide the answers to some of these questions.

The energy required for growth is best measured by the daily deposition of gross energy in the new substance added during growth. Protein and calcium requirements are best measured in the same way. This is easy to say, but its accomplishment takes time and a great amount of detailed work in carrying out the necessary chemical analyses. Extensive work of this kind has been done at the Illinois and Texas stations.

The Energy Requirement for Growth.—Until rather recently, poultrymen have been so much concerned with the protein, vitamin

and mineral requirements for growth that they have paid little attention to the energy requirement. In fact, until these other requirements were known, so that the minimum amounts for rapid growth could be specified, there was little reason for being concerned about energy. But with reasonably complete information available about protein and vitamins, the question of energy takes on new significance. The ration which, in addition to supplying all other known requirements, will furnish the greatest amount of productive energy per pound, will probably give the best results in practice, at least for growing chickens. Quantitatively, the requirement for energy is by far the largest of the several nutrients needed for growth, and it therefore usually determines the requirement for total feed.

TABLE 24.—PRODUCTIVE ENERGY OF SOME POULTRY FEED INGREDIENTS FOR GROWTH. (*From Texas Agr. Exp. Station Bulletin 678.*)

Ingredient	*Moisture* %	*Protein* %	*Fiber* %	*Productive energy (calories)* per pound	per quart*
Alfalfa meal, 20%	7.5	20.3	18.4	314	190
Alfalfa meal, 15%	8.0	15.6	27.2	261	160
Barley, ground	9.4	13.1	6.0	811	890
Blood meal	9.6	79.4	1.5	1004	1800
Bone meal, special steamed	2.8	8.6	2.5	202	400
Buttermilk, dried	8.0	34.1	0.4	707	850
Casein	10.6	81.9	0.2	1016	1200
Corn, ground	10.9	9.9	2.1	1145	1700
Corn, ground, 15% moisture	15.0	9.4	2.0	1092	1600
Corn distillers' solubles	5.0	27.0	1.0	853	1100
Corn gluten meal	8.8	44.6	3.0	839	1400
Cottonseed meal, 41%	7.8	40.7	11.4	659	1000
Fish meal, 64%	7.8	67.3	0.4	898	1200
Hominy feed	10.4	12.7	5.8	851	940
Linseed meal, o.p., 32%	9.0	32.6	9.0	569	630
Liver meal	8.6	63.8	1.0	1092	1800
Meat and bone scrap, 50%	6.3	51.0	2.1	724	1100
Meat and bone scrap, 55%	6.3	57.6	2.9	724	1100
Milo, ground	10.7	11.8	2.3	1144	1900
Molasses	27.3	3.3	0	714	2100
Oat hulls	6.5	4.6	30.2	0	0
Oat meal, feeding	9.0	10.2	3.0	1155	2000
Oats, ground	9.3	12.0	10.9	760	530
Peanut meal, 43%	6.1	43.8	11.6	731	1100
Rice bran	8.5	12.8	12.8	771	620
Skim milk, dried	5.6	35.0	0.2	525	630
Soybean meal, 41%	9.2	43.9	5.8	649	930
Soybean meal, solvent, 46%	9.8	46.0	5.7	565	800
Tankage, 60%	7.5	60.5	2.1	676	1100
Wheat, ground	10.4	13.5	2.4	1024	1700
Wheat bran	9.3	17.3	9.1	478	240
Wheat brown shorts	10.4	17.7	6.2	581	460
Wheat white shorts	10.3	16.2	2.2	983	1200
Whey, dried	5.9	12.8	0.2	490	760
Yeast, dried	6.6	47.0	3.3	476	780

* Approximate

At this point it is necessary to explain what is meant by productive energy. Most of the ingredients used in poultry rations contain energy. The exact amount of gross energy in a particular ingredient or ration can be determined by complete combustion of a sample in a bomb calorimeter. The gross energy of the feed, minus the fecal and urinary energy in the droppings, represents metabolizable energy. (In the case of ruminants it is necessary to deduct also the energy of combustible gases which result from fermentation, chiefly in the paunch.)

Not all of the metabolizable energy can be used by the animal because of wastage in metabolism. After this wastage, that is the cost of utilization, is deducted from the metabolizable energy, the difference is called net energy. Net energy is what is actually useful to the chicken for maintenance, including muscular activity, and for the production of fat, muscle tissue, and eggs. Productive energy, by definition, is the amount of energy stored in the form of fat or protein in a growing or fattening animal. When applied to growing chickens, it is actually the net energy of a feed or ration for growth or, in other words, the fraction of the net energy which can be stored.

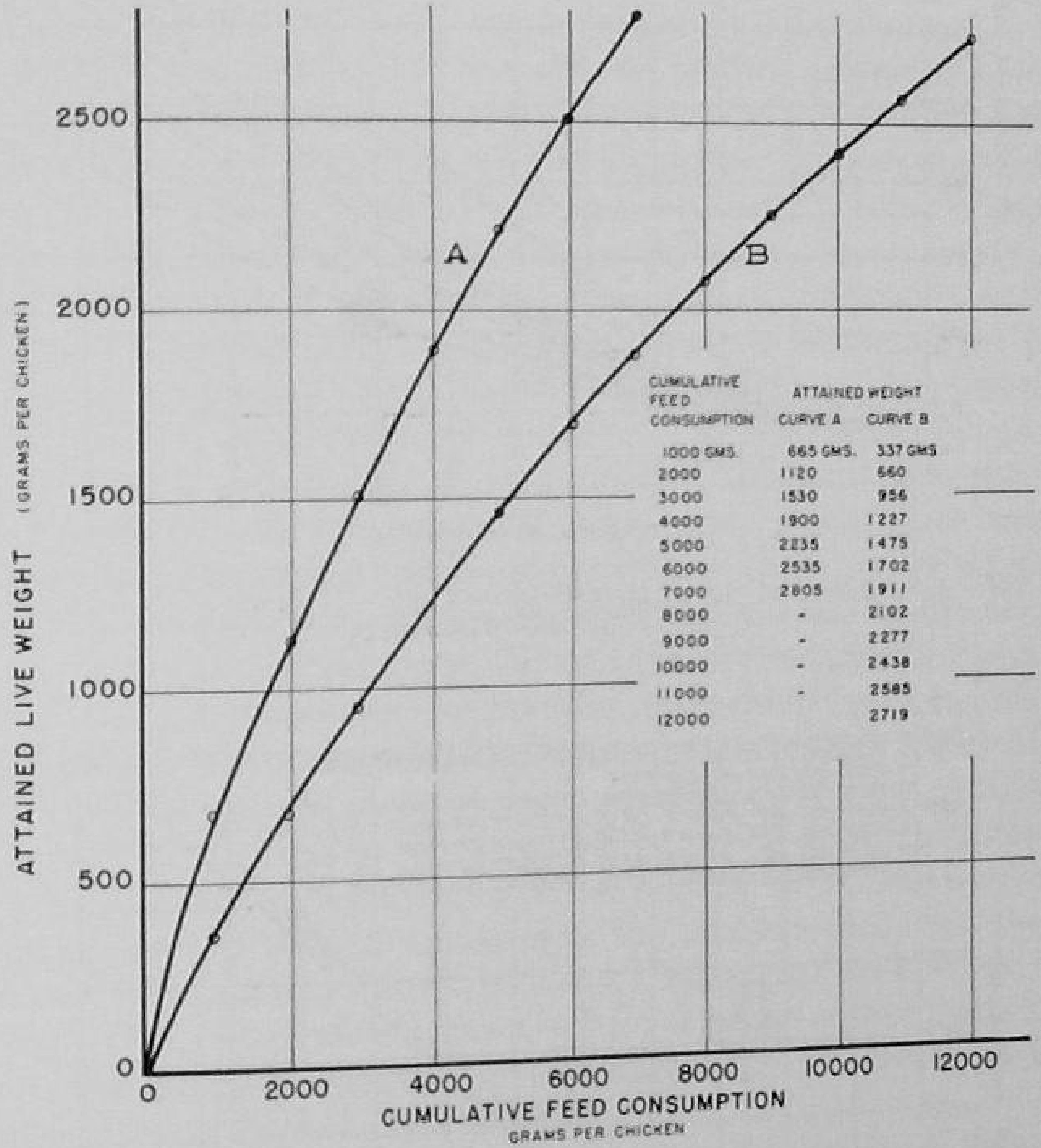
For rapid growth, the requirement is about 850 Calories of productive energy per pound of ration. This is not enough, however, for maximum efficiency of feed conversion (gain per pound of feed) or for maximum fat deposition or finish. Further research is needed to determine the proper levels for these purposes.

Since the bulkiness of a ration will affect the amount consumed, it is often desirable to consider Calories per quart as well as Calories per pound. Such ingredients as wheat bran and alfalfa meal, for example, tend to reduce the productive energy per quart more than productive energy per pound. The minimum requirement for rapid growth, when measured on the volume basis, is about 1100 Calories of productive energy per quart of ration.

Effect of Feed Intake on Growth.—It is well known that the amount of feed consumed is an important factor in determining how well chickens will grow, but the exact relationship between growth and feed intake is not so generally understood.

In a preceding section dealing with the energy requirement for maintenance, it was shown that there is an increasing demand for energy with increasing size of the animal, and we have seen that the energy requirement is closely related to the total feed intake. The combined effect of this relationship, and of the decreasing rate of growth after about the first eight weeks, results in a gradually increasing fraction of the feed supply being use for maintenance and, consequently, a decreasing fraction being used for growth, as the chicken matures. This is merely another way of saying that the law of diminishing increment applies to the utilization of feed for live-weight increase.

With chickens hatched in 1925, Jull and Titus were able to show that for each successive 1000 grams of feed consumed there is a proportionately smaller increase in live weight. The data for one lot of Rhode Island Red × Barred Plymouth Rock crossbred males in their experiment are shown graphically in Figure 133, along with comparable data for the New Hampshire × Barred Plymouth Rock crossbred males referred to earlier in Figure 86 and Table 19.



CUMULATIVE FEED CONSUMPTION	ATTAINED WEIGHT CURVE A	CURVE B
1000 GMS.	665 GMS.	337 GMS
2000	1120	660
3000	1530	956
4000	1900	1227
5000	2235	1475
6000	2535	1702
7000	2805	1911
8000	-	2102
9000	-	2277
10000	-	2438
11000	-	2585
12000		2719

FIG. 133.—Growth of chickens in relation to feed consumption. Both curves are for crossbred male chickens. Curve B in 1925; Curve A in 1950, showing the more rapid and efficient growth possible on the better rations now available.

Curve B of Figure 133 represents what was considered very good growth in 1925. Curve A shows the excellent growth obtained on the more efficient rations available twenty-five years later. In both cases, however, the value of each 1000 grams of feed, in terms of weight gains, was only about 90 per cent of the preceding 1000 grams. It is highly significant that 7000 grams of the 1950 ration produced as much weight in 16 weeks as 12,000 grams of the 1925 ration did in 22 weeks.

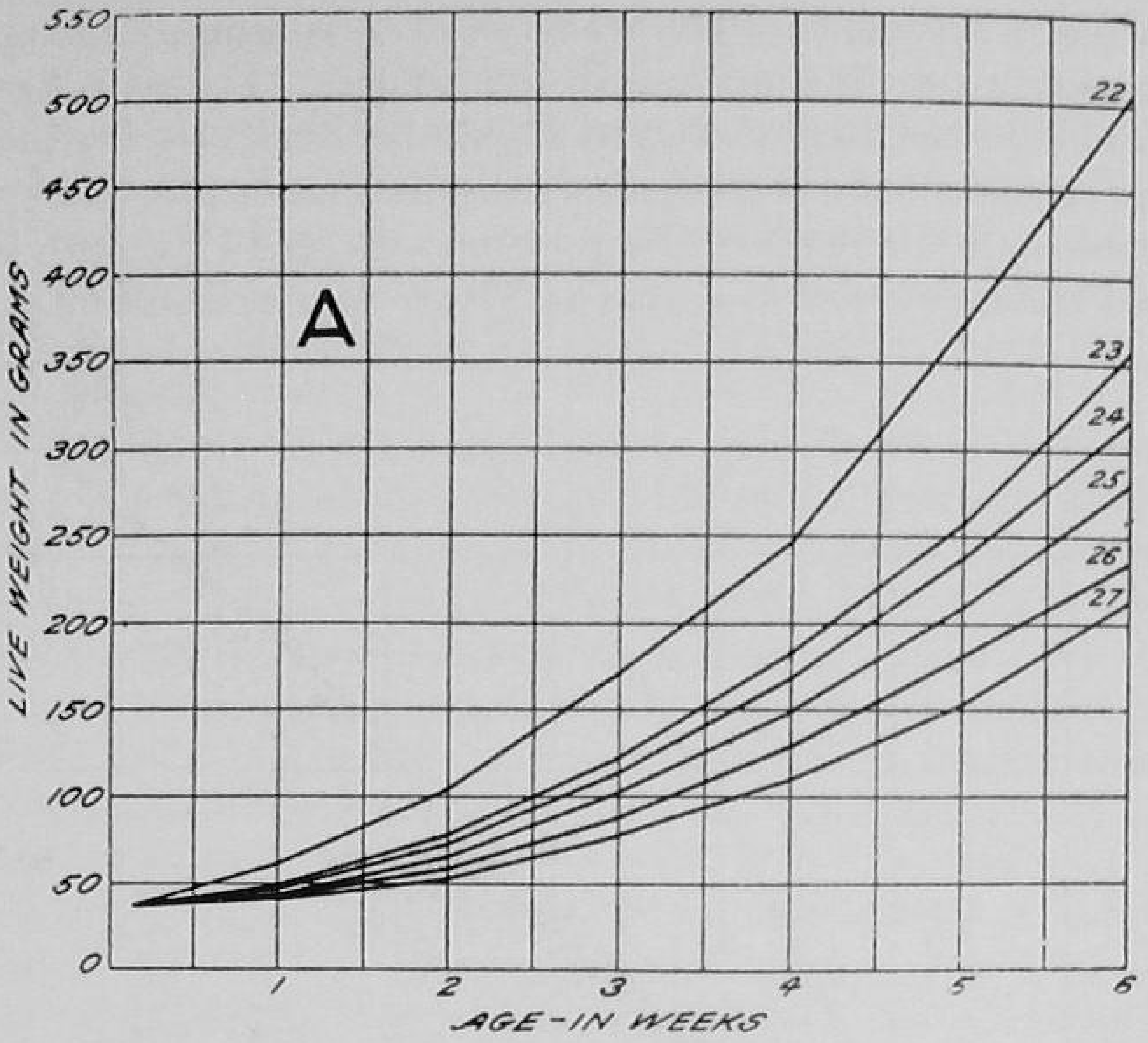


FIG. 134.—Live weight of chicks plotted against age. Compare with Figure 135. (*After Titus and Hendricks.*)

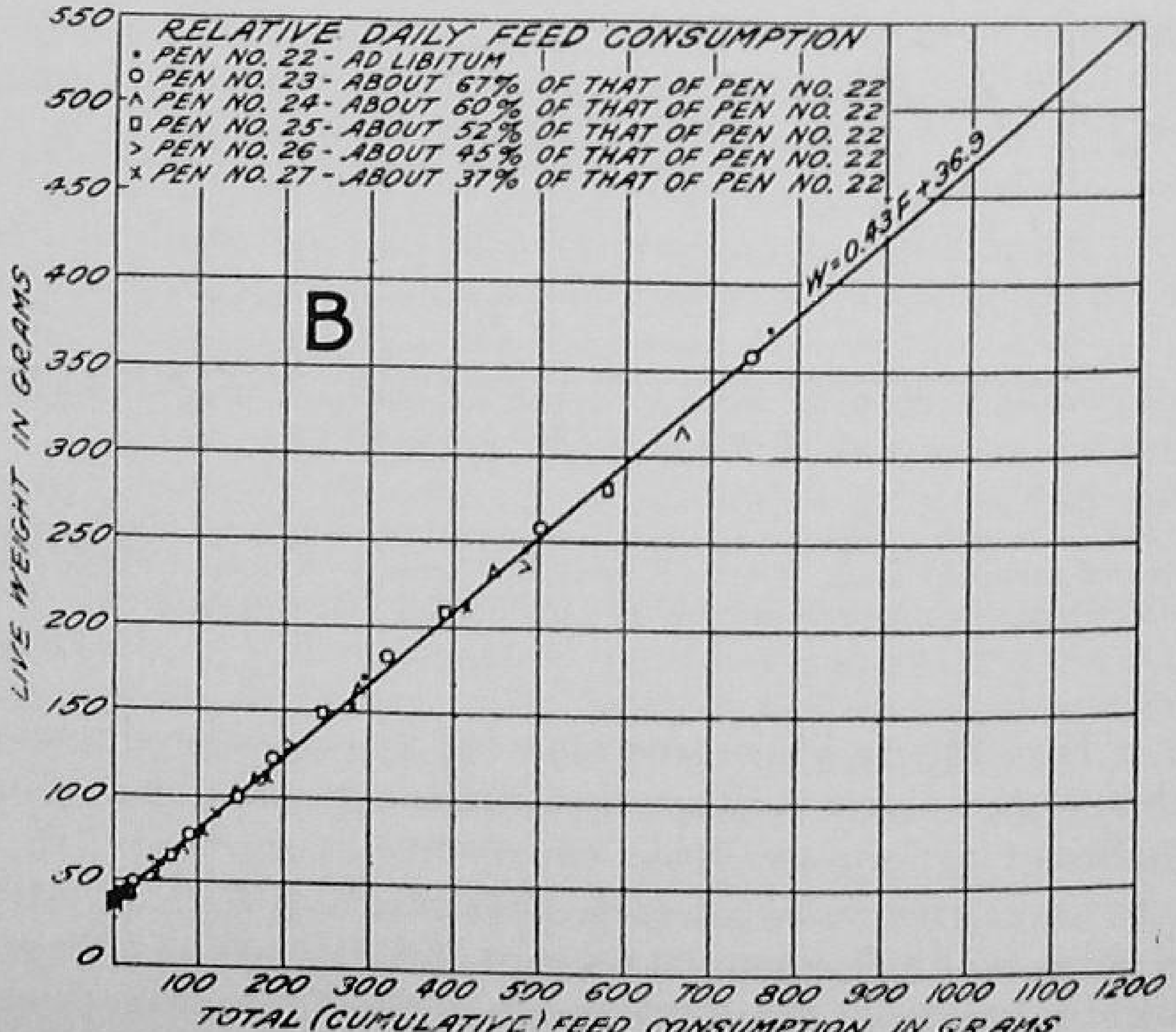


FIG. 135.—Live weight of the same groups of chicks shown in Figure 134, but plotted against the total cumulative feed intake. (*After Titus and Hendricks.*)

Further evidence that growth is a function of feed intake was presented by Titus and Hendricks. The data from one of their experiments are shown graphically in Figures 134 and 135. Six pens of 40 Rhode Island Red chicks were fed the same diet for six weeks but in different amounts. The chicks in one pen were allowed free access to feed at all times. Those in the other five pens were given daily 67, 60, 52, 45 and 37 per cent, respectively, of the amount eaten by the control pen. In Figure 134 the successive weekly average live weights are plotted against age, and the differences in rate of growth are clearly apparent. In Figure 135 the same weekly average live weights are plotted against the total cumulative feed intake, and it will be seen that the data for each of the six lots fall along the same straight line. The authors point out that there is no significance to the fact that the line is straight rather than curved, for in another experiment the corresponding data all fell along a curved line. The point of importance is that the rate of growth was a function of the total (cumulative) feed intake rather than of time. Stated in a practical way, it means that in the case of several lots of chicks fed the same ration, or in all probability if fed equally good rations of different makeup, one could more accurately predict or estimate the average live weight at any time during the first six weeks from a knowledge of the total feed consumption than from a knowledge of the age of the chicks. As the chicks grew older, and the maintenance requirement became an increasingly important matter, the relationship failed to hold.

The Protein Requirement for Growth.—The protein requirement could be assessed by a complete amino acid analysis of the new tissue laid down day by day or week by week in rapidly growing chickens. This has not yet been attempted on a comprehensive basis. Several workers have, however, approached the problem from the standpoint of the minimum level of a specified amino acid which will promote maximum growth when fed in a ration so formulated as to be nutritionally adequate in all other respects. Much of this work has been done at the California station.

Glista, at the Illinois station, using a forced feeding technique, has recently determined the requirement for each of the essential amino acids in terms of the amount necessary to promote an average daily gain of 8 per cent in 10- to 15-day-old male crossbred chicks. He found a distinctly lower minimum requirement for methionine than has been reported by other workers. When the protein content of the entire ration is 20 per cent, his results show the following values for the five critical amino acids.

	Per cent of ration
Arginine	1.0
Lysine	0.8
Methionine	
(without cystine)	0.65
(with 0.5% cystine)	0.35
Tryptophane	0.20

Recommended allowances for these and several others are given in Table 28. In this connection it is important to remember that a complete deficiency of any one of the dietary essential amino acids (those which cannot be synthesized by the chicken) will completely prevent the formation of any new protein tissue. A partial deficiency will limit the amount of such new protein which can be formed.

In much the same way, the requirement for those amino acids which are difficult or impossible for the chicken to synthesize varies in proportion to the level of protein fed. A balance must be maintained, so that a given dietary essential amino acid always forms the same percentage of the total protein in the ration—at least up to the limit of maximum protein utilization. As pointed out earlier, however, it is usually necessary to give particular attention only to the five critical amino acids when formulating practical chick rations.

It has become customary to standardize the protein level in starting rations for chicks at about 20 per cent, and it is well known that the level can be lowered as the chickens increase in weight so that 15 per cent, or even less, is satisfactory for adult fowls. It seems entirely possible that for maximum early growth, *i.e.*, during the first few days after hatching, the protein level might well be 25 or even 30 per cent instead of 20. This view is supported by the fact that the observed *percentage* rate of growth is highest right after hatching and decreases steadily with increasing body weight. Furthermore, the protein content of the unabsorbed egg yolk, which furnishes the chick with food immediately after hatching, is over 40 per cent on the dry basis.

It is only during this early period of extremely high percentage rate of growth, and while maintenance requirements are very low, that any such high levels of protein could be utilized to advantage. Increasing the protein level to 25 or 30 per cent for as long as five or six weeks may easily result in less total gain than is obtained on a 20 per cent protein ration. A well balanced ration, with no great excess of any required nutrient, is as important for maximum growth as for promoting any other function.

The Mineral Requirements.—Certain mineral elements must be added to rations for young chicks if normal growth is to be obtained. Several others, known to be needed in small amounts, are normally present in the common feed ingredients in sufficient amounts to take care of the requirements for growth.

The recommended allowance of calcium is 1.0 per cent of the total ration. Phosphorus should be supplied at the rate of 0.6 per cent of the feed, and not less than one-third of this amount should be in the form of non-phytin phosphorus. Much of the phosphorus in feeds of plant origin is phytin phosphorus which must be sup-

plemented by additional phosphorus from such sources as steamed bone meal.

Sodium chloride, or common salt, should be added to the extent of 0.5 per cent of the total ration. It may be iodized salt in order to supply the iodine requirements, and it may also be manganized so as to furnish the needed manganese. Manganese is needed at the rate of about 25 milligrams per pound of total feed, because only about 5 per cent of the manganese eaten is absorbed from the digestive tract.

The Vitamin Requirements.—Most of the vitamin requirements of growing chicks have now been worked out so that they can be stated in exact terms. The recommended allowances, which include a margin of safety, are given in Table 27.

THE REQUIREMENTS FOR EGG PRODUCTION

Since the rate of egg production varies greatly in different individuals and at different seasons of the year, the only way of stating the nutrient requirements specifically is in terms of the nutrients contained in a unit of the product, that is, in an egg of specified weight. From such a statement of the requirements it is then possible to make any necessary allowances for variation in rate of egg laying. An egg weighing 2 ounces will contain about 7.5 grams of crude protein (N × 6.25), about 2 grams of calcium and about 95 Calories of gross energy. If a hen is laying every day, and if her eggs average 2 ounces in weight, it is obvious that these amounts of nutrients must be added to her maintenance and activity requirements. If she is laying on alternate days, one-half of these amounts of nutrients must be provided daily.

As an example of the method by which the foregoing information may be used in calculating the feed requirements under specified conditions, we shall use a flock of 400 hens, weighing 5 pounds (2268 grams) each, and laying at the rate of 300 eggs a day. We shall assume that the environmental temperature is such that food energy will not need to be used for the express purpose of maintaining body temperature. Calculations will also be made to show to what extent the requirements may be furnished by a good grade of corn.

The Energy Requirements.—The total energy requirement of these hens will consist of their basal heat production, their activity requirements and the energy stored in eggs, assuming that they are neither gaining nor losing weight. The basal energy requirement is found by estimating the basal heat production of the entire flock. The basal heat production of adult hens is about 2.75 Calories per kilogram of live weight per hour. For 400 hens weighing 2268 grams each this would amount to 59,875 Calories every 24 hours.

It has been shown that the net energy value of corn for chickens is 2.8 Calories per gram of corn. By the use of this factor it is seen that (59,875/2.8 =) 21,384 grams, or 47.1 pounds of corn will be required daily to furnish the energy for basal heat production.

Since the energy requirement for normal activity is about one-third of the basal energy requirement, (47.1/3 =) 15.7 pounds of corn will be needed to furnish the energy for normal activity. The "gross" maintenance requirement may then be said to be (47.1 + 15.7 =) 62.8 pounds of corn.

The energy stored in 300 eggs amounts to (300 × 95 =) 28,500 Calories, and to supply this there will be needed (28,500/2.8 =) 10,179 grams, or 22.4 pounds, of corn. Hence, by simple addition, the total energy requirement of this flock of hens under the conditions specified would be met by (47.1 + 15.7 + 22.4 =) 85.2 pounds of corn.

The Protein Requirements.—The protein needed for the various physiological functions of these hens may be calculated in a similar manner. It has been shown that the nitrogen requirement for maintenance, for several species of animals, is 0.002 gram per Calorie of basal heat production. Assuming that the same figure is correct for the fowl, calculation shows that 59,875 × 0.002, or 120 grams of nitrogen will be needed for maintenance. Converted into conventional protein, by multiplying by 6.25, this is 750 grams of protein. Assuming a biological value of 50 per cent for the protein of corn, this would mean a minimum of 1500 grams of digested and absorbed protein. Then, on the assumption that the protein of corn is 75 per cent digestible by the fowl, it would take 2000 grams of dietary corn protein to meet the requirements. Since corn contains only about 9 per cent of protein, it would be necessary to feed (2000/.09 =) 22,222 grams, or 49 pounds, of corn daily to supply the amount of protein required by these 400 hens for maintenance.

In 300 eggs there would be (300 × 7.5 =) 2250 grams of protein. Using the same factors (50 per cent biological value, 75 per cent digestibility and 9 per cent of protein in corn), the quantity of corn needed to supply the protein in 300 eggs is found to be 147 pounds. Hence 49 + 147 = 196, the number of pounds of corn required to make possible the formation of the protein in 300 eggs, as well as to provide the protein used in maintenance. Since muscular activity does not require the expenditure of protein, no calculation in respect to that factor is necessary.

It should be understood that this 196 pounds of corn is not in addition to the 85.2 pounds required for energy. The quantity that must be fed is determined by whichever of the calculated results is the larger. In this case the feeding of 196 pounds of corn would be required to furnish the minimum amount of protein needed. It would furnish more than the necessary amount of

energy. This is one reason why corn alone is neither a suitable nor an economical ration for laying hens.

Corn is an excellent source of energy but, since it is deficient in most of the critical amino acids, it is not a good source of protein.

It is much more difficult to determine the amino acid requirements of laying hens than of chicks, and not very much information is available. The few studies reported suggests a minimum requirement for leucine of 1.35 per cent, lysine 0.50, tryptophane 0.15, methionine 0.38, and methionine and cystine combined 0.63 per cent. If any one of the amino acids known to be essential for egg production is omitted entirely, laying will stop in 4 or 5 days. Neither the normal amino acid composition of such eggs as are laid, nor their ability to hatch, seems to be affected.

The Calcium Requirements.—Calcium is of considerable importance in the ration of laying hens because of the quantities needed in egg shell formation, but not even the maintenance requirement for calcium can be furnished by corn alone. Using the factor mentioned previously, 4 grams of dietary calcium per 100 grams of net protein used for maintenance, calculation shows that $(7.5 \times 4 =)$ 30 grams of calcium will be needed daily for maintenance. Corn contains only 0.02 per cent of calcium. Hence $30 \div 0.0002 =$ 150,000 grams, or 331 pounds, of corn that would be needed to supply the calcium requirements for maintenance. This is about three times as much as the flock would eat if given free access to corn under favorable conditions.

In 300 eggs there would be about 600 grams of calcium. Assuming, as before, that calcium is only about 50 per cent retained by the body, the dietary amount required becomes 1200 grams daily for the conditions specified. In attempting to furnish this from corn alone, calculation shows that it would be necessary to feed $(1200 \div 0.0002 =)$ 6,000,000 grams, or $6\frac{1}{2}$ tons of corn daily to a flock of 400 hens in order to provide the calcium needed in the formation of 300 eggs each day. This, of course, reduces the matter to an absurdity. Even granting that on a restricted calcium intake there might be a great increase in the percentage retained, and assuming for the moment that all of the calcium in corn might be utilized, it is still apparent that it is physically impossible to supply the calcium requirement from corn alone. In actual practice the need for calcium is usually met by feeding crushed oyster shell or ground limestone *ad libitum*.

An adequate supply of calcium in the ration is unfortunately no guarantee against the production of eggs with rough or thin shells. Furthermore, the mere feeding of extra calcium will not overcome the well-known decrease in shell quality which is characteristic of many high-producing hens and flocks during the latter part of the laying year, and may even make matters worse. Added manganese has been shown to help in some instances, but there are other unknown factors involved.

There is a marked increase in calcium deposition in the bones of pullets just before they begin to lay, and it is therefore important to provide oyster shell free choice for about a month before egg laying is expected to begin.

Other mineral requirements of hens are summarized in Table 27.

The Vitamin Requirements.—Some of the vitamin requirements of laying and breeding hens are more intense than the corresponding requirements for growing chicks, and it is often said that the most critical test of a poultry ration is to find out whether it will enable a flock of breeding hens kept indoors to produce eggs of high hatchability.

The requirements of breeding hens for vitamin A are nearly twice those of young chicks, and for vitamin D two and one-half times.

Riboflavin is an exception to the general rule in that the requirements of breeding hens are slightly less, and those of laying hens producing market eggs are distinctly less than those of young growing chicks.

The actual recommended allowances are indicated in Table 27.

The Total Feed Requirement.—The foregoing calculations have all been based upon a specific weight of hen and a specific rate of egg production. In actual practice, it is necessary to allow for variation in average weight, and for variation in rate of lay. Total feed intake will also be influenced by the size of eggs laid, as well as by the environmental temperature and the amount of voluntary activity.

In terms of annual egg production it is reasonable to assume that small eggs will be offset by large eggs, and that the effect of low temperatures will be offset by periods of high temperature. The effect of activity can also be considered in terms of average conditions. This leaves body weight and rate of lay as the two variables which are of most importance.

Assuming that the ration is reasonably well balanced for egg production, the total amount required by a hen in one year can be calculated very closely from the formula $F = 25 + 8W + E/7$, in which F is the number of pounds of feed required, W is the average weight of the hen in pounds, and E is the number of eggs laid during the year.

Thus, for a hen weighing 5 pounds and laying 210 eggs, the total feed required would be 25 plus 8×5 plus 210/7, or 25 plus 40 plus 30, a total of 95 pounds.

Each added pound of live weight adds 8 pounds to the yearly feed requirement, and each 7 eggs laid adds one pound. It takes as much feed to maintain an extra pound of live weight of hen as it does to produce an extra 56 eggs of average weight.

According to the formula (see also Table 25), a 4-pound hen laying 210 eggs would require 87 pounds of total feed in one year,

while a 6½-pound hen would require 107 pounds of feed to do the same job. Or to put it in another way, the 107 pounds of feed consumed by a 6½-pound hen laying 210 eggs would be sufficient for a 4-pound hen laying 350 eggs.

TABLE 25.—POUNDS OF FEED REQUIRED BY HENS OF DIFFERENT WEIGHTS IF THEY LAY THE INDICATED NUMBERS OF EGGS IN ONE YEAR

Average weight, pounds	Number of eggs per year					
	0	70	140	210	280	350
3.5	53	63	73	83	93	103
4.0	57	67	77	87	97	107
4.5	61	71	81	91	101	111
5.0	65	75	85	95	105	115
5.5	69	79	89	99	109	119
6.0	73	83	93	103	113	123
6.5	77	87	97	107	117	127
7.0	81	91	101	111	121	131

The same relationship can of course be applied to the daily feed intake of a flock, with average live weight and rate of lay as the other variables. In this case the formula becomes $F = 6.85 + 2.2W + E/7$, in which F is the daily feed intake of 100 hens of "W" pounds average weight when laying at the rate of "E" eggs per 100 hens per day. Daily feed requirements for 100 hens weighing 4, 5 and 6 pounds each, and laying at different rates, are shown in Table 26.

TABLE 26.—AVERAGE AMOUNTS OF FEED REQUIRED PER DAY AND PER DOZEN EGGS BY 100 HENS OF DIFFERENT WEIGHTS AND EGG PRODUCTION. (TWO-OUNCE EGGS ARE ASSUMED.)

	Feed consumed by:					
	4-pound hens		*5-pound hens*		*6-pound hens*	
Eggs per 100 hens per day	*Per day*	*Per dozen eggs*	*Per day*	*Per dozen eggs*	*Per day*	*Per dozen eggs*
0	15.6	—	17.8	—	20.0	—
10	17.0	20.5	19.2	23.2	21.4	25.7
20	18.5	11.1	20.7	12.4	22.9	13.7
30	19.9	8.0	22.1	8.8	24.3	9.7
40	21.3	6.4	23.5	7.1	25.7	7.7
50	22.8	5.5	25.0	6.0	27.1	6.5
60	24.2	4.8	26.4	5.3	28.6	5.7
70	25.6	4.4	27.8	4.8	30.0	5.1
80	27.0	4.1	29.2	4.4	31.4	4.7
90	28.5	3.8	30.7	4.1	32.9	4.4
100	29.9	3.6	32.1	3.9	34.3	4.1

OTHER SPECIAL REQUIREMENTS

Maintenance, growth and egg production are the important considerations in the feeding of most poultry flocks, but there are certain other processes that at times become quite important.

The Requirements of Molting Hens.—By the chemical analysis of a large number of chickens at different weights, it has been shown that in White Leghorns ranging from 1 to 5 pounds in weight the feathers contain from 20 to 25 per cent of the protein in the entire bird, and that except in the case of nearly mature pullets, in which body fat becomes of great significance, the feathers also contain from 12 to 21 per cent of the gross energy. This at once suggests that the requirements for feather growth are no small item in the metabolism of the molting hen.

The gross weight of feathers on a 4-pound pullet will be about 100 grams, and of this amount 12 grams will be nitrogen. This is equivalent to the nitrogen in 10 eggs, but it undoubtedly represents a much greater requirement for dietary protein than does the production of 10 eggs. This is because of the relatively high sulphur content of feathers, which presupposes a rather intense requirement for dietary sulphur that is available only in the amino acids cystine and methionine.

It is sometimes considered that because egg production ceases during the molt, the feed supply may be reduced. As a matter of fact, this is usually not advisable. If molting hens are in good flesh their feed requirements are probably somewhat less than when they are laying. If they are in poor physical condition, as often happens, they should be well fed so that they will gain in weight.

The Requirements for Fattening.—It is ordinarily assumed that there is very little wastage of energy in the metabolism of fat deposition. In the mature animal that is being fattened the energy requirement appears to be about 7 Calories per gram of weight increase during a fattening period, and the protein requirement about 0.2 gram of net protein per gram of gain. Presumably these values would apply, at least approximately, in the case of fattening poultry, The feed energy would have to be higher than the stated amount by the quantity necessary to allow for losses in digestion, and the feed protein would have to be sufficient to allow for losses in both digestion and metabolism.

The Water Requirements.—The uses of water in the body of the fowl, especially as they relate to digestion, metabolism and the regulation of body temperature, have been discussed in a previous chapter. Some facts concerning water requirements will be presented here.

The entire physiological mechanism in the fowl is admirably adapted to the conservation of water. Water used in digestion is used again in other ways. Even the rather large amount of water used in carrying away the waste products from the kidneys is largely reabsorbed from the cloaca and used again in various body processes.

The water balance in the fowl may be indicated by saying that the water consumed is equal to the sum of (1) the water stored in

the tissues; (2) the water used in egg formation; (3) the water vaporized; and (4) the water excreted in urine and feces; minus (5) the amount of metabolic water formed in the oxidation of food materials. The amount of water required would have to include that used in digestion but, since it may be used also for any of the other four purposes, it does not become an additive fraction of water consumed.

The average water intake of laying hens is about 35 to 40 pounds per 100 hens per day. Large hens laying at a high rate in hot weather may require 50 to 60 pounds. When there is no egg production, water intake is closely related to the consumption of dry matter. High-protein rations, and those high in salt or in any diuretic, increase the normal needs for water.

FORMULATING RATIONS

Important as is the conception of minimum nutrient requirements in setting up feeding standards, any careful student of the subject will soon come to the conclusion that it is possible to determine the specific requirements for any purpose far more accurately than they can be supplied in practice. Furthermore, the practical application of feeding standards, after they have been set up in detail, is likely to be found chiefly in evaluating certain feeding

TABLE 27.—RECOMMENDED NUTRIENT ALLOWANCES FOR CHICKENS (IN PERCENTAGE OR AMOUNT PER POUND OF FEED)

	Starting chicks	*Breeding hens*
Total protein, per cent	20[1]	15
Vitamins:		
Vitamin A activity (International Units)	2000	3300
Vitamin D (International Chick Units)	135	340
Thiamine, mg.	0.9	?
Riboflavin, mg.	1.6	1.3
Pantothenic acid, mg.	5.0	5.0
Nicotinic acid (niacin), mg.	8.0	?
Pyridoxine (vitamin B_6), mg.	1.6	1.6
Biotin, mg.	0.045	0.07
Choline, mg.	700	?
Minerals:		
Calcium, per cent	1.0	2.25[2]
Phosphorus, per cent[3]	0.6	0.75
Salt, per cent	0.5	0.5
Manganese, mg.	25	15
Iodine, mg.	0.5	0.5
Potassium, per cent	0.2	?

[1] For growing chicks, the protein content of the ration may be reduced to 16 per cent after the first eight weeks.

[2] This amount of calcium need not be incorporated in the mixed feed. Calcium supplements fed free choice are considered as part of the ration.

[3] At least 0.4 per cent of the total feed should be inorganic phosphorus. About 30 per cent of the phosphorus of plant products is non-phytin phosphorus, and may be considered as part of the inorganic phosphorus required.

TABLE 28.—RECOMMENDED ALLOWANCES OF THE ESSENTIAL AMINO ACIDS FOR CHICKENS FROM 0 TO 4 WEEKS OF AGE

Amino acid	*Per cent of the ration*	*Amino acid*	*Per cent of the ration*
Arginine	1.2	Leucine	1.4
Methionine	0.9	Phenylalanine	1.6
or		*or*	
Methionine[1]	0.5	Phenylalanine[3]	0.9
Cystine	0.4	Tyrosine	0.7
Lysine	0.9	Threonine	0.6
Tryptophane	0.25	Valine	0.8
Histidine	0.30	Isoleucine	0.6
Glycine[2]	1.0–1.5		

[1] Cystine will replace methionine as long as the ration contains not less than 0.5 per cent of methionine.

[2] The chick can synthesize glycine, but the synthesis does not proceed at a rate sufficient for maximum growth.

[3] Tyrosine will replace phenylalanine as long as the ration contains not less than 0.9 per cent phenylalanine.

TABLE 29.—AMINO ACID COMPOSITION OF INGREDIENTS COMMONLY USED IN POULTRY RATIONS. (ALL FIGURES ARE PERCENTAGES.)

	Crude protein	*Arginine*	*Lysine*	*Methionine*	*Cystine*	*Tryptophane*
Alfalfa meal	20	1.0	1.0	0.36	0.38	0.35
Barley	12	0.5	0.3	0.13	0.20	0.13
Barley	9	0.4	0.2	0.10	0.15	0.10
Blood meal	84	3.0	7.2	1.00	1.50	1.18
Buttermilk, dry	32	1.0	2.2	0.67	?	0.41
Corn	9	0.4	0.2	0.21	0.15	0.07
Corn gluten meal	42	1.3	0.7	0.97	0.68	0.33
Cottonseed meal	43	3.5	1.6	0.71	0.97	0.46
Distillers solubles, dry	26	0.8	0.8	0.41	0.26	0.12
Fishmeal	70	5.0	6.4	2.20	1.18	0.98
Fishmeal	65	4.6	5.9	2.00	1.10	0.91
Fishmeal	60	4.0	5.4	1.80	1.00	0.84
Fish solubles, condensed	35	1.5	1.7	0.60	0.21	0.12
Linseed meal	35	2.7	1.1	0.84	0.66	0.56
Liver meal	56	2.9	3.4	0.84	0.78	0.70
Meat scrap	55	3.9	3.4	1.10	0.77	0.44
Meat scrap	50	3.0	2.7	0.70	0.60	0.35
Meat scrap	45	2.7	2.2	0.50	0.45	0.27
Milo	11	0.4	0.3	0.16	0.20	0.09
Oats	12	0.7	0.4	0.23	0.19	0.14
Oats	9	0.5	0.3	0.17	0.14	0.10
Peanut meal	44	4.4	1.3	0.49	0.70	0.44
Peas, dry	24	1.7	1.4	0.19	0.34	0.19
Rice, rough	8	0.6	0.2	0.11	0.10	0.10
Rye	12	0.5	0.4	0.16	?	0.16
Sesame meal	45	4.0	1.3	1.44	0.59	0.54
Skim milk, dry	35	1.1	2.5	0.81	0.42	0.45
Soybean meal	45	2.8	2.7	0.62	0.66	0.53
Sunflowerseed meal	45	3.7	1.9	1.53	0.72	0.59
Wheat	13	0.5	0.3	0.21	0.24	0.14
Wheat	10	0.4	0.3	0.16	0.19	0.11
Wheat bran	15	0.9	0.5	0.17	0.19	0.21
Wheat middlings	16	0.9	0.4	0.14	0.19	0.14
Whey, dry	12	0.4	1.0	0.32	0.41	0.18
Yeast, dry	45	2.0	3.1	0.84	0.54	0.55

practices, rather than in any revolution in the methods of formulating rations. To be useful to the practical feeder, the results of such scientific material as has been discussed in the early part of this chapter must be translated into terms that can be applied easily and quickly.

The data in Tables 27, 28, 29, and 30 furnish the basis for such application. They have been taken from a report on Recommended Nutrient Allowances for Poultry published by the National Research Council, and prepared by its sub-committee on poultry nutrition.

EVALUATING A RATION

In order to determine the value of a ration for a particular purpose, it is necessary to consider not only its content of specified nutrients, but also its palatability, its physiological effects on the fowls to be fed, its possible effect on the product (meat or eggs), and its cost.

Palatability.—Both chicks and hens often show distinct preferences for certain feed ingredients or mixtures, and they do not take readily to new feeds. It may be as difficult to get adult fowls to eat yellow corn if they have been fed exclusively on wheat and oats, as to get another flock to change from corn to wheat. Some hens will carefully pick out corn from a mixture of several grains while others will just as carefully select wheat.

Attractiveness, as influenced by sparkle and by color, is of some importance. Grits which shine and sparkle are usually chosen in preference to those which are dull. Green is a favorite color, as determined by attractiveness of feed or water. Water which has been colored green is usually taken in preference to other colors or to clear water. Green marbles are often used by turkey growers to attract young poults to their feed. Other colors are much less effective.

Feed consumption is also affected by the physical condition of the feed. Very fine mixtures are not so readily eaten as are feeds which are more coarsely ground. Similarly, feeds which become very sticky when moistened are not relished, as a rule. And it is obvious that size of ingredients is of some importance, depending on whether one is mixing a ration for baby chicks or for laying hens.

Unless care is taken in formulation, the fiber content of a starting ration may easily be so high as to prevent chicks from eating as much as they would voluntarily consume, thereby reducing both weight gains and the efficiency of feed conversion.

Physiological Effect.—It is necessary to consider the physiological effect of a feed or ration as well as the various nutrients which it contains. Linseed meal, for example, though high in protein, cannot be used to advantage in poultry rations except in small quantities, unless it is given special treatment. At levels above 3

TABLE 30.—AVERAGE COMPOSITION OF POULTRY FEED INGREDIENTS. *(Data from the National Research Council.)*

	Per cent									*Milligrams per pound*							
Feed	*Moisture*	*Protein*	*Fat*	*Fiber*	*N-free extract*	*Ash*	*Calcium*	*Phosphorus*	*Iron*	*Manganese*	*Copper*	*Cobalt*	*Carotene*	*Thiamine*	*Niacin*	*Riboflavin*	*Pantothenic acid*
Alfalfa meal, dehydrated, 20% protein	7.1	20.9	2.9	19.8	38.2	11.1	1.7	0.31	0.04	28.6	7.1	0.17	60	3.1	17.3	7.4	18.5
Barley, excluding Pacific Coast	10.6	12.7	1.9	5.4	66.6	2.8	0.1	0.47	0.005	8.3	5.1	0.01		1.7	24.1	0.8	3.7
Bone meal, steamed special	3.3	13.4	9.7	1.1	1.2	71.3	29.3	15.1	0.08	5.1	9	0.03		0.9	2	0.4	0.8
Brewers' dried yeast	6.3	46.8	1.2	2.8	35.7	7.2	0.1	1.52	0.01	2.4	15.1	0.08		43	213.6	14	49.1
Buttermilk, dried	7.6	32.4	6.4	0.3	43.3	10	1.4	0.94		1.5				1.7	2.8	15.8	13.5
Corn, yellow dent	15	8.9	3.9	2	68.9	1.3	0.02	0.27	0.002	2.3	0.9	0.01	1.3	1.7	9.8	0.5	2.6
Corn gluten meal, 41% protein	8.6	42.9	2	3.9	40.1	2.5	0.2	0.41	0.05	4.4	13.1	0.04	10		24.8	0.7	3.8
Cottonseed meal, 41% protein	7.8	41.2	6.2	11.2	27.7	5.9	0.2	1.14	0.008	12.9	7.7	0.06		1.8	13.0	2.5	4.4
Distillers' dried solubles	6.9	28	6.7	3.3	47.6	7.5	0.4	1.4	0.05	45.4	36.3	0.09		2.7	54.3	5.2	8.9
Fish meal, menhaden	6.4	62.2	8.5	0.7	4.2	18	5	3.4	0.06	10	3.9	0.08		0.2	25.9	2.4	
Fish meal, sardine	6.9	67.2	5	0.6	5.4	14.9	4.2	2.54	0.03	10.3	9.2	0.08				2.5	
Hominy feed, white, 5% fat	10.1	10.8	5.7	4.7	66	2.7	0.05	1.03	0.004	8.2	9.9			5.9	25.1	1	3.1
Linseed oil meal, o.p., 33% protein	8.8	35	5.6	8.1	36.9	5.6	0.4	0.94	0.024	19.1	11.8	0.17		3.9	18.9	1.9	7.5

Meat scrap, 52% protein	6.9	52.9	7.3	2.2	4.3	26.4	8.7	4.4	0.05	4	5.5	0.09	0.03	27.1	2.4	2.1
Meat scrap, 60% protein	6.2	60.9	8.8	2.4	1.1	20.6	6.3	3.5	0.04	5.4	3.7	0.04	0.1	23.7	2.5	2.3
Molasses, cane	26	2.9	0	0	62.1	9	0.7	0.08					0.4	20.9	1.1	17.9
Oats, excluding Pacific Coast	9.8	12	4.6	11	58.6	4	0.1	0.43	0.008	19.2	2.4		2.9	8.2	0.4	6.8
Oatmeal, feeding	9.3	15	7.4	2	64.4	1.9	0.1	0.43	0.006	13.6	1.6	0.02	3.5	4.5	0.6	6.6
Peanut oil meal, 43% protein	7.2	43.1	7.6	13.9	23	5.2	0.2	0.54					3.3	77.5	2.4	24.1
Rice bran	9	12.8	13.1	12.7	41.7	10.7	0.1	1.36		70.9			10.3	129.1	1.4	10.3
Rice polishings	9.7	12.7	11.4	3.5	56.6	6.2	0.04	1.1					8.8	325	0.9	5.5
Skimmed milk, dried	5.8	34.7	1.2	0.2	50.3	7.8	1.3	1.1	0.005	1.2	5.2	0.03	1.5	5.7	10	16
Sorghum, kafir	10.5	11.2	2.9	2.3	71.1	2	0.04	0.33	0.008	7.5	3	0.03	1.6	18.3	0.5	5.7
Soybean meal, 44% protein	9.2	44.2	5.3	5.6	29.9	5.8	0.3	0.66	0.015	14	7.7	0.05	0.8	16.7	2	6.1
Soybean meal, solvent extracted	9.4	46.1	1	5.9	31.8	5.8	0.3	0.63	0.01	13.8	6.8		1.4	17.1	1.4	6.2
Wheat, northern spring	9.9	15.8	2.2	2.5	67.8	1.8	0.05	0.41	0.005	33	4.9		2.3	28.8	0.5	6.4
Wheat bran	10.3	16.4	4.3	9.9	53	6.1	0.1	1.3	0.016	56	4.9	0.05	3.9	63.5	1.4	13.6
Wheat flour middlings	10.3	18.1	4.6	4.9	58.5	3.6	0.1	0.65	0.002	39	2.1		6	44.2	0.8	4.5
Wheat standard middlings	9.9	17.6	5	6.7	56.6	4.2	0.1	0.78	0.009	53.6	9.8	0.04	5.8	44.3	0.8	9.3
Whey, dried	6.5	12.2	0.8	0.2	70.4	9.9	0.9	0.91	0.021	1.1	24.2	0.05	1.8	5.1	13	22.4

per cent it is very laxative and reduces both the rate and efficiency of gain. The unfavorable effects of rye have been mentioned previously.

Many other ingredients affect the character of the droppings, and this becomes important in the feeding of baby chicks. Rations containing soybean meal as the only protein supplement have been observed to cause more "pasting up" in chicks than rations supplemented with fish meal or milk products. Dehulled solvent-process meal causes less trouble, suggesting that some constituent of the beans is responsible for the sticky condition of the droppings. In some trials, antibiotics have apparently eliminated the problem. The pasting can also be avoided by feeding 25 to 50 per cent cracked grain during the first few days after hatching. Presumably the pasting is merely one symptom of a digestive disturbance which is caused by some constituent of soybean meal. The young chick is particularly susceptible to this trouble, while older ones are less easily affected. Further research is needed to determine exactly what is involved.

Some feeds enhance, while others partially inhibit the deposition of yellow pigment in the shanks of growing chickens.

Milk has a definite diuretic effect, as does common salt if it is fed at levels much above 1 per cent.

Certain weed seeds are very unpalatable to poultry, and others are definitely toxic. Corn cockle is an example.

Effect on Product.—Though the composition of the feed usually has little effect on the composition of eggs, certain feeds do have an undesirable effect on the flavor of the eggs and on the flesh of fowls.

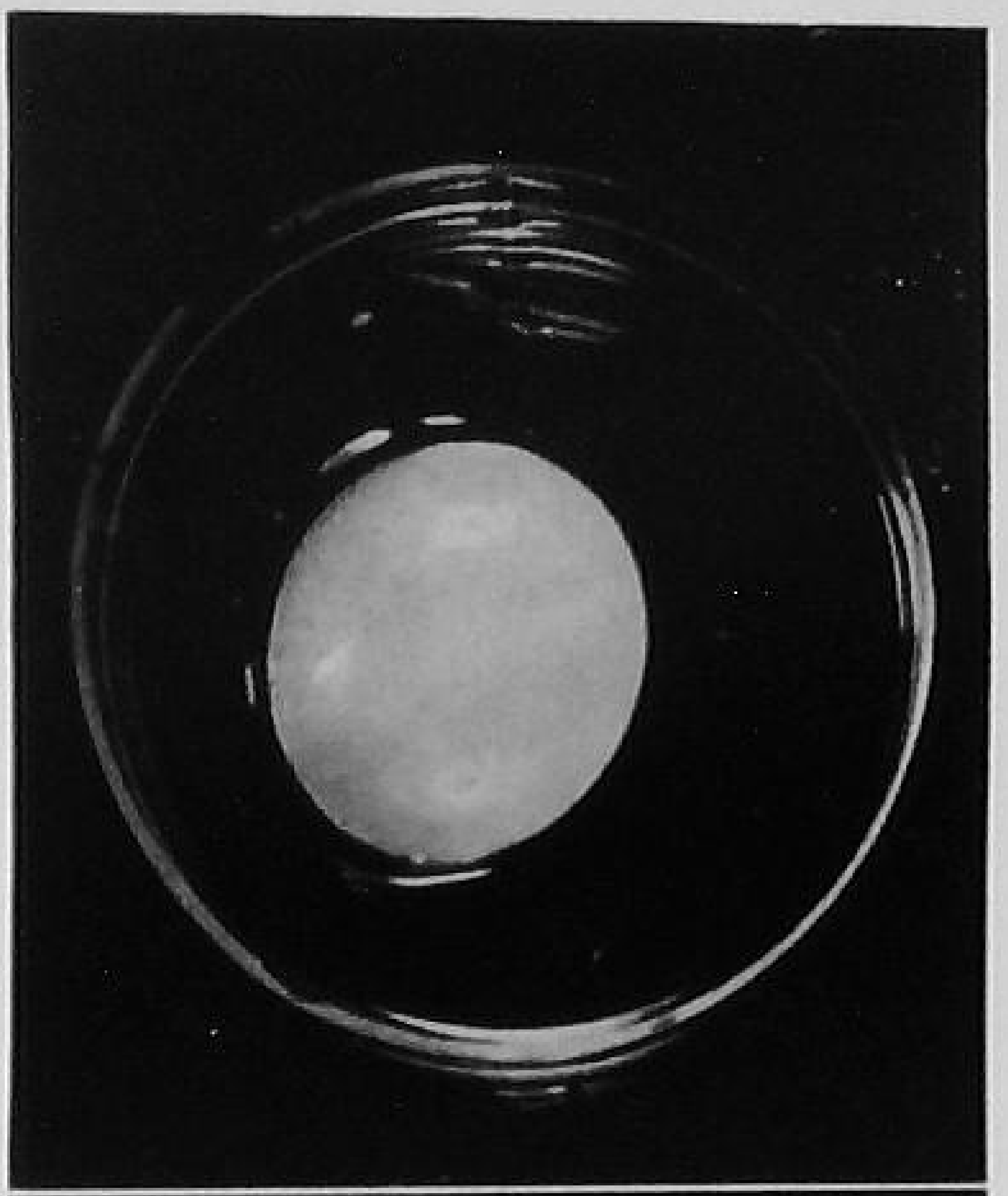
Green feed and yellow corn help to give the rich golden yellow color in the yolk which is greatly desired in some markets, while discriminated against in others. Tests at the Georgia Station showed that the feeding of 0.5 gram of dried ripe Pimiento pepper per hen per day imparted a desirable color to the yolks of eggs, and that the color or yolk could be deepened to a dark reddish-brown by feeding as much as 5 grams daily. Chicks hatched from the pimiento-colored eggs had more pigment in their shanks than did control chicks after both lots had received the same ration for a period of six weeks.

The effect of cottonseed meal on yolk color has been discussed in connection with the use of that product as a protein supplement. Another related plant, the common cheeseweed, *Malva parviflora*, also has an undesirable effect on eggs. Experiments conducted at the California Station have shown that if this weed is eaten in appreciable quantities by laying hens, the whites of their eggs will develop a pinkish color after being placed in cold storage.

Tests conducted at the National Poultry Institute, Newport, England, showed that greenish yolks were produced by hens fed the seed pods of the common weed, Shepherd's purse (*Capsella*

PLATE III

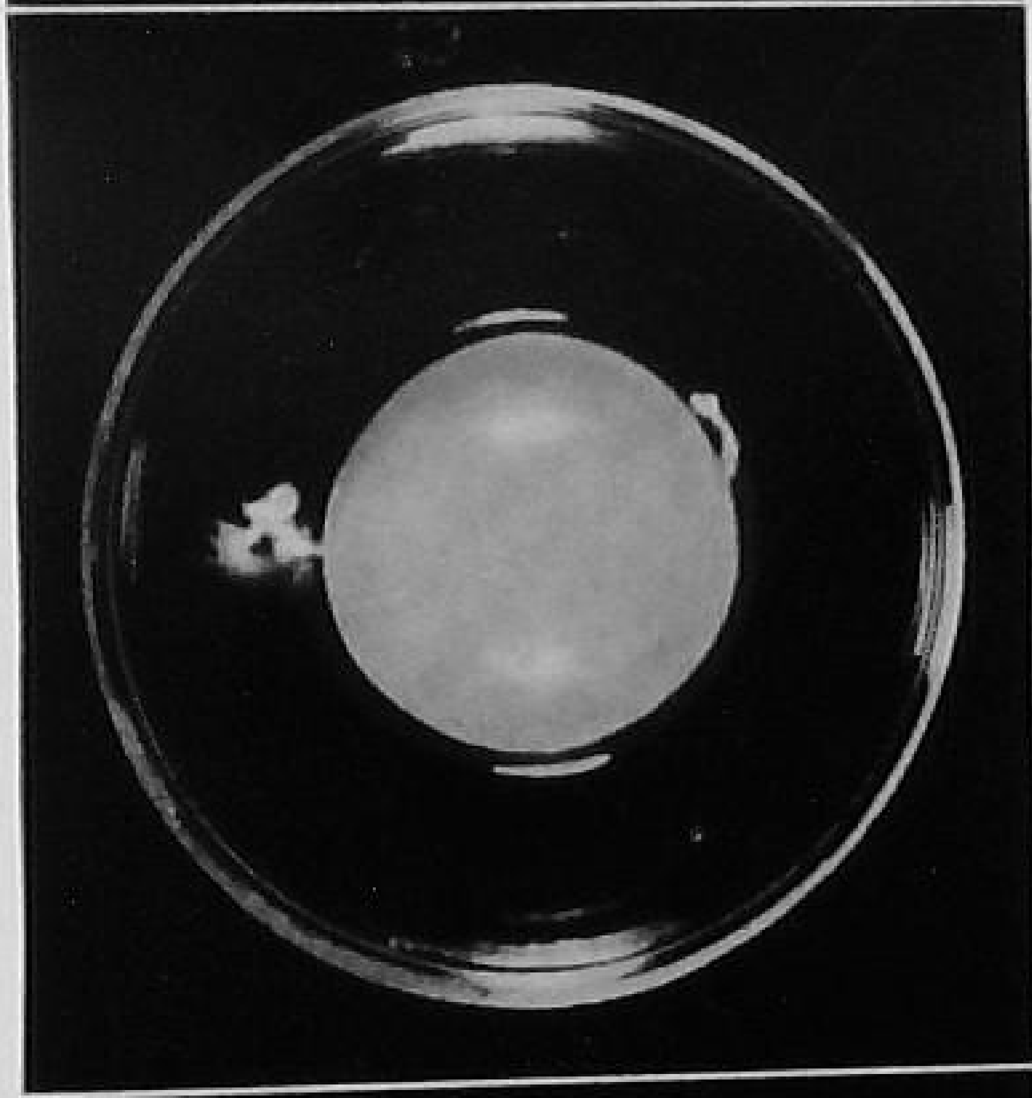
Yolk Color Is Directly Influenced by Feed



Extremely Pale Yolk

Produced by hens fed a mixture of—

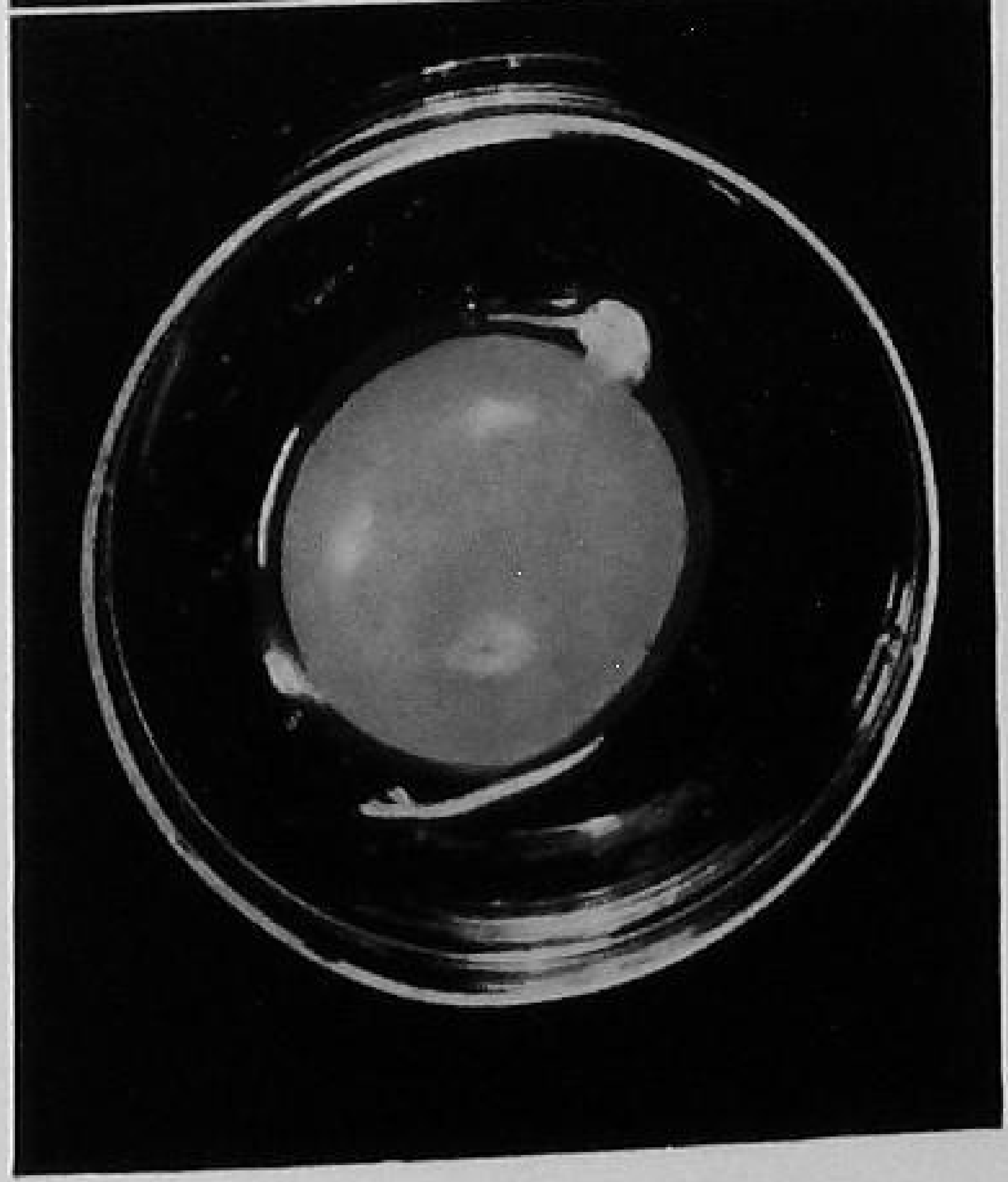
Oats 50%
Bran 50%
Occasional table scraps
No green forage



Medium-Colored Yolk

Produced by hens fed a ration of—

Yellow corn 50%
Wheat 25%
Oats 25%
No green forage



Deep Orange Yolk

Produced by hens fed a mixture of—

Corn 52%
Wheat 24%
Oats 14%
Dried milk and soy
bean meal 10%
Green grass pasture

These three examples of the influence of feed on yolk color were observed in three flocks near Urbana, Illinois. The spots appearing on the yolks are merely light reflections.

Courtesy of the Illinois Agricultural Experiment Station.

bursa-pastoris). Seed pods of another weed, pennycress (*Thlaspi arvense*), are also suspected of causing a similar discoloration.

Acorns, if germinated, were responsible for greenish-brown yolks, probably because of their content of gallic acid. Green, immature acorns caused no trouble, even when fed at the rate of 2 ounces per hen per day.

Cost.—A very important factor in any ration is its cost. The best ration, all things considered, is the one which gives the greatest economic returns. This does not mean either the greatest production or the cheapest ration. The greatest production might be obtained only from a ration that cost more than the product was worth, and the cheapest ration might result in such limited production that it would be as unprofitable as the most expensive ration. To find the most profitable mean between these two unprofitable extremes is the nice problem which confronts every practical feeder.

successful; while if it does not embody them it will surely fail. Many times the non-essentials of a system are emphasized and made to appear as the keystone of the ration; while, as a matter of fact, they are of no real importance whatever."

When to Feed Baby Chicks.—The common practice of most poultrymen is to withhold feed from young chicks until thirty-six to forty-eight hours after hatching. During the first twenty-four to thirty-six hours, at least, the chicks are better off in the nursery tray of the incubator, or in a standard chick shipping box, than they are in the average brooder. There is nothing to be gained by moving them to the brooder until they are old enough to be fed.

It is popularly supposed that when feeding is somewhat delayed, the yolk material which is taken into the body cavity just prior to hatching is more quickly and satisfactorily absorbed, and statements have frequently been made that too early feeding would interfere with normal yolk assimilation, even to the point of being a cause of mortality. The experimental results reported by several different investigators afford ample evidence that neither of these suppositions is correct. It has also been shown that the drinking of ice water during the first ten days after hatching did not interfere with normal yolk absorption, nor have any adverse effect on growth.

From the point of view of sound practice, there is no object in trying to feed chicks until they are hungry. Neither is there any reason for waiting until the lapse of some arbitrary number of hours after hatching before giving chicks their first feed. It is much more important to prevent them from filling their crops with indigestible material such as sand, shavings, or chaff, than to feed them at any specified time after hatching. Broiler chicks should be started on feed just as soon as they are hungry, in order to take full advantage of the ability of young chicks to make efficient weight gains.

Wet and Dry Feeding.—The feeding of wet mash, usually once a day, with the object of increasing total feed intake was once a rather common practice. The almost universal practice today is to feed the mash or ground feed dry in hoppers. Wet feeding is used for the final finishing period for fowls which are fed for a few days in batteries just prior to slaughter.

All-mash and Pellet Feeding.—With the success that has followed the use of all-mash rations for young chickens has come an interest in similar rations for hens. The necessity for rigid sanitation in many cases is a further reason for giving some consideration to this method of feeding. Perhaps the easiest way to change from the grain and mash to the all-mash system is to grind the grain mixture and add it to the ordinary mash. If grain and mash were fed in approximately equal quantities when fed separately, the percentage of protein supplement in the all-mash ration should be

one-half as great as in the mash fed in conjunction with scratch feed.

Pellet feeding, which has become of considerable importance in recent years, is a modification of the all-mash method. The ground mash mixture is forced through dies under high pressure and is thus formed into cylindrical pellets. Those for baby chicks may be only $\frac{3}{32}$ inch in diameter and $\frac{1}{8}$ inch long, while those for mature stock may be as large as $\frac{1}{4}$ inch in diameter and $\frac{3}{8}$ inch long. With this method of feeding, the chicks or hens have no opportunity of picking out certain parts of the mixture. If they eat the pellets, they all get exactly the same combination of ingredients.

Another advantage of pellets is that they enable chickens to eat much more of a high-fiber ration than they can when the same mixture is fed in mash form. Tests at Beltsville, Maryland showed that hens fed a ration consisting of 64 per cent oat hulls (21 per cent fiber) laid almost as well as the control lot, provided the ration was pelleted, and twice as well as similar hens fed the same high-fiber ration in mash form. Too much fiber in a mash mixture makes it impossible for hens to eat enough feed to lay well, or even to maintain their weight.

Still another innovation is the use of crumbled feeds. Pellets are passed under rollers which break them up into irregular-shaped pieces. The reason for this procedure is to encourage maximum feed consumption.

An argument that is sometimes advanced against both of the foregoing methods is that the fowls are likely to take less exercise under such a plan of feeding. This is probably true, but there is no experimental evidence to show that they will not voluntarily takes as much exercise as is necessary to their health and well-being.

Feeding Grain and Mash.—This is by far the most common practice in the feeding of laying hens, though the grain part of the ration is not always fed in litter. The whole philosophy of feeding layers, insofar as practice is concerned, is bound up in keeping them active and eager for feed, contented, and in good flesh.

The details of feeding practice, like the constituents of a ration, vary with feeders and conditions. As there is no one best ration, so there is no feeding routine for chickens that is outstanding in its excellence. The following practice, which has proved successful in a large number of cases where lights were not used to lengthen the feeding day, but where grain was fed in litter, is given as being suggestive of what a good routine may be:

Give a light feed of grain soon after the birds leave the roosts in the morning. This should be scattered in a deep litter to every part of the pen so that the birds will be kept busy for some time in searching for it. Fresh water should be supplied early in the morning, and replenished during the day as necessary.

Two to three hours before the birds go to roost they should be given a full feed of grain thrown in the litter. It is essential to the

best results that the birds go to roost with full crops, and this feeding should not be stinted. An examination of the crops of the birds should now and then be made after they are on the roosts to ascertain whether they are well filled.

It is better to overdo the matter of evening feeding a little than to slight it. If a little grain is left in the litter it will be eagerly scratched out in the morning.

Unless the weather is quite cool, fresh water should be supplied at the time of the evening feeding. In freezing weather commercial water heaters should be used, or other means provided to keep the water from freezing. Water must be available whenever the birds can see if the best production is expected.

Free Choice of Individual Feeds.—A question that is often asked has to do with whether or not the chick or the hen is able to balance its own ration when given the opportunity to do so by selecting from a number of individual feeds. Several investigators have studied this problem, but the results are not entirely conclusive. In tests at the Missouri Station, with nine different feeds available during the first eight weeks, White Leghorn chicks were able to select for themselves a ration of nearly uniform chemical composition, although varying considerably as to ingredients, averaging 18.1 per cent protein, 55.6 per cent carbohydrates, 4.7 per cent fat, 7.1 per cent ash and 3.5 per cent crude fiber. The makeup of the free choice ration in different weeks was as follows:

TABLE 31

Feed	First 2 weeks	4th week	6th week	8th week	Av. for 8 weeks
Corn meal	20.5	27.2	45.3	47.1	39.4
Wheat bran	27.8	20.9	12.4	3.1	11.1
Wheat shorts	33.7	33.4	23.9	28.9	29.3
Dried buttermilk	10.1	5.3	5.3	6.1	6.1
Dried skim-milk	1.8	4.7	4.3	3.7	4.8
Meat scrap	4.8	4.2	4.9	5.8	5.4
Alfalfa leaf meal	0.9	1.3	1.2	0.6	0.9
Bone meal	0.1	3.0	2.4	4.7	3.0
Salt	0.4	0.0	0.3	0.1	0.2
Total	100.1	100.0	100.0	100.1	100.2

At the Ontario Agricultural College chicks were raised on free choice diets, with some thirty different feeds available. The chicks were hatched in five different lots from February to May, and each group consisted of Barred Plymouth Rocks, White Leghorns, Wyandottes and Rhode Island Reds. Perhaps the most interesting result was that the February hatched chicks consumed over 2 pints of cod-liver oil to the 100 pounds of feed, whereas the May chicks consumed only one-fiftieth as much. In over 1200 birds there was not one with any trouble from crooked legs, slipped tendons, or

the like, and the free choice chickens, on the whole, were much more contented than the check lots.

In tests at the California Station, chicks did not show any preference between two rations identical in taste, texture, and appearance, when one contained and the other lacked riboflavin necessary for normal growth. Neither would they eat enough dehydrated alfalfa meal, when it was offered free choice, to prevent acute deficiency of riboflavin or subacute deficiency of vitamin A. They showed no consistent preference for rations containing no sugar and others containing up to 20 per cent of sugar. The chicks were able to distinguish between normal rations and those containing more than 2 per cent of salt, more than 2 per cent of powdered citric acid, or more than 0.03 per cent of quinine sulphate, and they showed a marked preference for the normal or basal rations in such cases.

Tomhave and Mumford at the Delaware Station compared the performance of two flocks of 100 yearling White Leghorn hens, one of which was fed an all-mash ration, and the other of which had to choose from 21 different ingredients that were kept continuously available. The experiment lasted for twenty-four weeks. Germinated oats and cod-liver oil were fed to both pens daily, as they were confined indoors throughout the test. The amounts of the several feeds consumed by the free choice group were as follows:

TABLE 32

Feed ingredient	Pounds	Feed ingredient	Pounds
Whole wheat	917	Ground soybeans	0.56
Whole oats	476	Limestone flour	0.44
Whole yellow corn	362	Gluten feed	0.38
Ground yellow corn	310	Flour wheat middlings	0.25
Cracked wheat	174	Fish meal	0.25
Dried buttermilk	74	Special bone meal	0.25
Oyster shells	47	Steamed bone meal	0.25
Limestone grit	33	Alfalfa meal	0.13
Wheat bran	10	Alfalfa leaf meal	0.05
Meat scraps	3	Ground oats	0.00
		Malt	0.00

There were 43 hens lost in the free choice pen as a result of prolapsus and pick-outs, and there were 8 such deaths in the check pen. Most of the mortality occurred during the last weeks of the experiment. Egg production in the check pen was much superior to that in the free choice fed pen. The authors concluded that yearling Leghorn hens do not have the ability or the natural instinct to select the proper proportions of different feeds to meet their physiological needs, when these feeds are placed before them in separate feeders.

Very little other information of this sort is available, and it can only be concluded that while free choice feeding of individual

bulb is all that is required, as the object is to provide just enough illumination to enable the hens to find food or water at any time of the night.

Poultrymen located in areas subject to blackout regulations during the war learned that a very low intensity of illumination was sufficient to stimulate egg production if directed at the hens while on the roost at night.

Effect of Light on Growth.—The lighting schedule also affects the performance of growing chickens. Partly grown cockerels taken into the laboratory have been shown to make consistently better gains over a period of several weeks when exposed to only 1, 4 or 9 hours of light in each 24-hour period than when given light for 12 hours or longer.

Recent tests at the Kansas station with young chicks showed that crossbred cockerels given alternate 2-hour periods of light and dark weighed 768 grams at six weeks of age, 15 per cent more than comparable groups fed the same ration but subjected to alternate 12-hour periods of light and dark during the same six-week period. Furthermore, most of this weight differential was maintained until the chickens reached broiler size of about three pounds.

Little practical use has been made of this kind of information, although it is well known that neither growing chicks nor adult fowls need more than perhaps eight hours a day to consume their necessary feed requirements, even on all-mash rations. With pelleted feeds and grain, the minimum time can be still further reduced.

HOUSING PRACTICE

The principles of successful poultry housing have been fully discussed in a previous chapter, but there are a few common practices rather closely related to the housing problem that will be treated briefly here.

Housing Pullets in the Fall.—The move from range to permanent winter quarters is most important in the life of young pullets, and the way it is done often distinguishes a real poultryman from a man who simply keeps chickens.

It is important that within each group housed at any one time, all pullets be of about the same degree of maturity. A uniform flock makes for easier and more effective feeding and management. Many poultrymen feel that it is best to house pullets just as they are beginning to lay. Others follow the practice of placing nests on the range and leaving the pullets there until the rate of production is about 25 per cent.

The new house will be strange to the pullets, and they may become timid and easily frightened. If they have been hopper fed both grain and mash on the range, the same practice should be continued indoors. Litter will be something new to them, and it

may be some time before they learn to find grain which is thrown in it. Changes in the water supply from what they have been accustomed to on the range may also be a problem.

The pullets should be watched at roosting time for the first few nights to be sure that they find the perches instead of the nests, feed hoppers, or window sills. One advantage of low roosting racks instead of conventional roosts and droppings boards is that the pullets learn to roost in the proper place with less trouble to the caretaker.

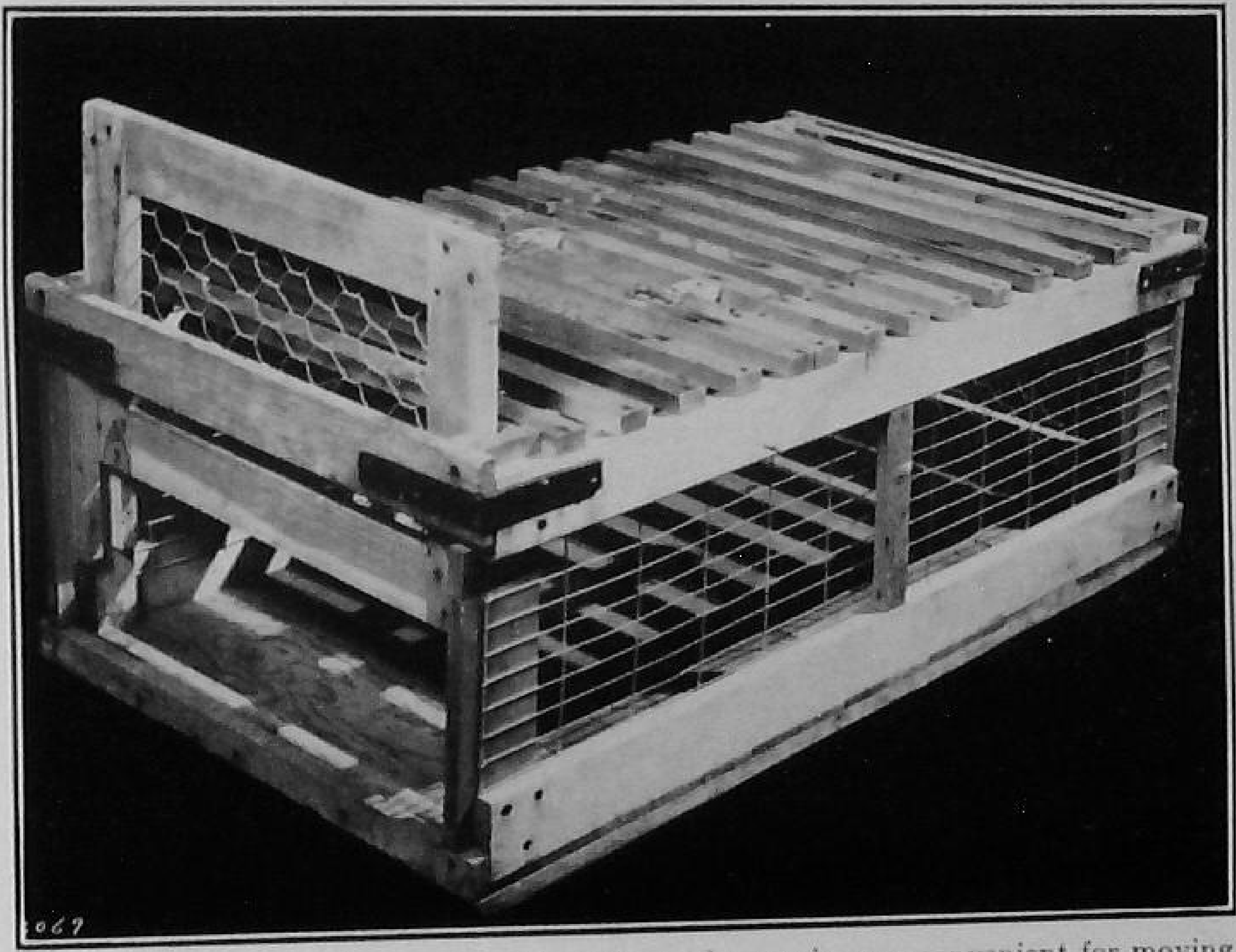


FIG. 138.—A catching crate with sliding end gates is very convenient for moving pullets and hens, and for easy handling of flocks at culling time. (*Courtesy of Minnesota Agricultural Experiment Station.*)

Flock Segregation.—In connection with feeding it has been suggested that uniform flocks are essential to the best results. Likewise, in presenting the principles of successful brooding and rearing, the importance of sorting chicks according to size rather than according to age was emphasized. In the same way, it is desirable, whenever housing facilities permit, to separate the pullets from the older hens, to separate the medium from the late molters when both are to be carried over the winter, and, perhaps most important of all, to separate the breeding flock from the laying flock so that the former can be given the best possible care and attention during the winter months.

Protection from Extreme Cold.—The use of a limited amount of heat in poultry houses during severely cold weather has already

methods work at different times and under different conditions. Some of the procedures suggested are:

1. Give the flock more room, or reduce the size of the flock by culling.

2. Use an anti-pick salve on at least 25 per cent of the flock—both picked and unpicked birds.

3. Sprinkle fine salt, free of lumps, generously over the mash for three to five days.

4. Feed whole, heavy oats either free-choice in hoppers or by hand to the extent of 5 or 6 pounds daily to 100 hens.

5. Keep the chickens busy by hanging a pulled cabbage or other attractive material in such a position that the chickens have to jump up slightly to peck at it.

6. Make use of commercial appliances such as shields over the vent, or guards on the beak or in front of the eyes.

7. Debeak the offenders by cutting the upper mandible back to the quick, or by using a commercial electric debeaking outfit.

Since vent picking often starts while hens are at the feed hoppers, it is good practice to place the hoppers at floor level, just high enough to clear the litter, or high enough so that a hen eating from the hopper cannot be picked by another standing on the floor.

Salt in the drinking water is often effective. It should be used for a half-day at a time on two or three successive days. A heaping tablespoonful to each gallon of water is about right.

CHAPTER 12

CONTROLLING DISEASES AND PARASITES

LOSSES from disease and from parasites can be very serious, and it is important for the poultryman to be familiar with the most effective means of prevention and control in order to keep such losses at a minimum. Constant vigilance is the price of success in this phase of poultry management.

The death loss of chickens on farms during the five years 1945 to 1949, inclusive, expressed as a percentage of the number on hand January 1, was 17.7, 17.4, 17.9, 17.6, and 19.1, according to reports of the U. S. Department of Agriculture. Average figures for individual states for the 5-year period range from 14 to 23 per cent. At 1949 values this meant a loss of more than $140,000,000, without taking into account the losses among broilers and among young chicks raised for replacement of laying and breeding flocks.

Various estimates place the monetary loss to the poultry industry at more than $250,000,000 a year. Not all of this loss can be prevented, but ways of reducing it are certainly worthy of special study. Of much more direct concern to the individual flock owner are such losses as 30 or 40 per cent of a flock of young chicks from bronchitis or pullorum disease, or more than a month's egg production following an outbreak of Newcastle disease.

THE NATURE OF DISEASE

The disease problem may be looked upon as a constant struggle between the host and the invading organisms. The flock owner sits as a sort of referee whose interests and sympathies are entirely with the host but who is too often helpless to do much more than watch a losing battle, while all of his profit and some of his capital are hauled away to an incinerator or disposal pit.

If the poultryman is to avoid this unhappy circumstance, he must become, in effect, a health officer for his flock. He must plan and carry out a program of flock management which will turn the tide of battle always, or nearly always, in favor of the host. There are three distinct approaches to such a program. The first is to adopt strict sanitary and quarantine procedures which will keep host and disease organisms apart. For example, it is obvious that if chickens can be kept continuously under conditions such that the cholera organism can never gain entrance, they will not be

sanitary and quarantine measures which are effective for almost any type of infection.

Methods of Sanitation and Quarantine.—The practice of sanitation is not always simple, and it is not easy. If carelessly or only partially followed it is of very little value, but if rigidly carried out it can be highly effective. An excellent example of what a careful sanitation and quarantine program can accomplish is furnished by the experience of the Regional Poultry Research Laboratory at East Lansing, Michigan. Through a period of 11 years after the laboratory was established, the stock was kept free from all diseases other than the one with which they were working, namely, the avian leukosis complex. The only exception was the infrequent occurrence of coccidiosis, and this disease was kept under control. During the eleven years they had no pullorum disease, no bronchitis, no colds or coryza, no cholera, no typhoid, no laryngotracheitis, no Newcastle, no fowl pox, no lice, no mites, no roundworms, no tapeworms. In other words, the sanitation procedures actually worked. Not until the spring of 1950 did any contagious virus disease, other than lymphomatosis, occur. In May of that year there was an outbreak of infectious bronchitis. The source of the infection was not positively determined, but circumstantial evidence pointed strongly to an unfortunate break in the sanitation procedures.

The essential points in the sanitation and quarantine plan in effect at the laboratory are:

1. A "closed" breeding flock is maintained. Hatching eggs were purchased at the beginning, and no stock has been added since. This is highly important.
2. Quarantine measures are rigidly carried out, as indicated in some detail in the following statements.
3. No chickens from outside sources are accepted for diagnosis.
4. No one can go on the plant without passing through a locker room in which shoes and outer clothing are changed. Lunch buckets, watches, pocket knives and other personal items are passed through an ultra-violet sterilizing cabinet before being taken into the plant. Working clothes are furnished by the laboratory as a protection to the experiments being conducted.
5. The plant is divided as between isolation breeding flocks and those used for transmission experiments. Individual caretakers work exclusively on one side or the other. Furthermore, a change of shoes is made on leaving or entering each house.
6. No visitors are allowed on the plant at any time.
7. Employees are prohibited from keeping chickens at home, simply as an added safeguard against introducing infection.
8. All chicks are started in batteries and transferred to brooder house pens with wire panel floors.

9. All buildings are screened against wild birds, flies and mosquitoes. Insects have been controlled also by the use of DDT, Lindane, and pyrethrins in oil-base sprays.
10. All feed is delivered in bulk, and elevated to bins in the feed house, so that neither truck nor driver is ever on the plant. Furthermore, the truck is washed before leaving the mill, and the driver makes no intermediate deliveries before reaching the laboratory. A similar type of small bulk delivery is used on the plant itself.
11. The plant has its own water supply from a deep well and an enclosed water tower.
12. All chickens are raised and maintained in complete confinement within screened buildings.
13. The pens and equipment are cleaned regularly and thoroughly, and steam sterilized after each cleaning.
14. The litter used in the laying and brooding pens was chosen because it is subjected to high temperatures during the manufacturing process.
15. A vigorous campaign is maintained to keep out rats, mice, and other wild rodents.
16. All refuse, litter, feces, etc., go to a compost pile in a remote corner of the plant. The composted material is removed by way of a back entrance about once in two years. Carcasses and offal are buried in a trench with quicklime. Those involved in autopsy are incinerated.

Such a complete program would of course be difficult to carry out on a commercial basis, and it probably has no place in the management of farm flocks. But the principles on which it is based are sound, and many of them can be applied much more widely than at present, with distinctly profitable results. Simpler programs have repeatedly been shown to be practical and reasonably effective.

What, then, are the steps in a practical sanitation and quarantine plan which can be carried out in connection with the management of both farm and commercial flocks? Most authorities and experienced operators would agree on the following procedures, with certain variations and additions under special conditions.

1. Avoid the introduction of partly grown or adult stock. Breeders should maintain closed flocks. Others should make necessary introductions by means of eggs or chicks from best known sources.
2. Isolate and rear chicks away from adult stock. Grow chicks indoors, or provide enough land so that range-grown chicks do not occupy a given area more often than once every three years. If chicks from two or more sources are to be grown at the same time, isolate them from each other during the first two months.

3. Avoid traveling directly from the adult flocks to the chick range, if at all possible. If the business is large enough to make it practical, have separate caretakers for chicks and hens.
4. Keep visitors out of the houses and yards, especially those whose business takes them from farm to farm.
5. Maintain clean, sanitary quarters. Have a clean water supply. Use feeders which reduce waste to a minimum, and prevent contamination of feed by the chickens. Avoid spillage of feed where it will attract wild birds and rodents
6. House pullets and hens separately. This is not only good management, but it protects the pullet flock from infections which may be spread by "carrier" hens.
7. If such diseases as fowl pox and laryngotracheitis are a problem on the farm or in the community, vaccinate all fowls on the premises, and continue to vaccinate each new crop of chickens year after year. (See also discussion under Newcastle disease and bronchitis.)
8. Follow procedures which will keep the fly nuisance at a minimum. In certain areas it may be equally important to control mosquitoes and other biting insects.
9. Keep the poultry areas sufficiently well fenced to prevent the escape of chickens to neighboring farms, and to prevent chickens from other flocks from gaining access to the premises.
10. If a breeding program is being conducted on the farm, practice rigid selection in order to make use of high-viability families, year after year.

HOW TO RECOGNIZE DISEASE

Since complete protection through sanitation and quarantine is rarely possible under farm or ranch conditions, it is important to be able to recognize disease and parasitic infestations in their early stages. Most poultrymen have to acquire this ability through costly experience, because no amount of written information can take the place of knowledge gained by daily contact with a poultry flock and close observation of conditions as they change and develop from season to season.

The experienced poultryman is constantly on the alert for signs of unthriftiness. He notices the fact that some of the young chickens are slow to come out of the brooder house in the morning, or that certain hens remain on the roost instead of coming down to feed as usual. He quickly identifies the hens which are inactive, or those which stand in a corner with their feathers all ruffled up instead of competing with their pen-mates at the feed hopper. Such conditions may be only temporary, or they may be signs of more

serious trouble, and the responsibility of deciding which they are rests squarely on the flock owner in most instances.

Since many death losses, especially in fowls of laying age, are of a non-specific type, not known to be related to disease organisms, and therefore not capable of spreading to other fowls in the flock, the poultryman must learn to distinguish between various sorts of morbidity before he can hope to apply control measures effectively. This calls for experience, and can be only partially learned from books.

Pathologists at the California Station, in autopsying about 7000 chickens of laying age, more than two-thirds of which came from commercial flocks, found that more than half of the deaths resulted from pathological conditions quite unrelated to infection, parasitism, or other specific disease manifestations. This non-specific mortality is a serious poultry problem to which there is as yet no completely satisfactory answer. Selection of breeding stock on the basis of family survival offers a most encouraging prospect for successful control.

WHAT TO DO WHEN DISEASE OUTBREAKS OCCUR

A sick or dead bird should be considered as a warning, depending somewhat on conditions, and not merely as something to be disposed of promptly. An attempt should be made to determine the cause of death in order that one may decide what steps need to be taken to prevent further loss. Prompt and accurate diagnosis is absolutely essential to any intelligent plan of disease eradication and control. Many local veterinarians have received special training in the diagnosis and control of poultry diseases, and are in a position to give expert assistance. If such a man is located in the community, by all means make use of his services. If no competent help is available, specimens may be sent to a state laboratory for diagnosis. Obviously, not every chicken that dies should be sent to the laboratory for examination, but any indication of more than a normal loss should be the occasion for getting diagnostic help as soon as possible.

It is, of course, important to remember that mere post-mortem examination is not always sufficient to permit diagnosis. Special tests, bacteriological cultures, or animal inoculations may be necessary. These take time. But effective control measures depend, first of all, on an accurate diagnosis. If specimens have decomposed before arrival at the laboratory it is usually quite impossible to determine the exact cause of death. The following suggestions on how to select and ship specimens for diagnosis were prepared by the Department of Veterinary Medicine at the Oregon Agricultural Experiment Station, and should be equally applicable elsewhere.

1. Select birds showing symptoms typical of the disease in the flock. Do not choose a bird because it "acts differently."
2. Select 2 or 3 mature birds or 5 to 7 brooder chicks for examination. Autopsy of a single bird may be misleading.
3. Live specimens are the most satisfactory for examination.
4. If dead birds are sent in, they should be strongly wrapped to prevent seepage from the carcass. In warm weather they should be packed in ice.
5. Diseased organs or tissues may be packed solidly in powdered borax, in a can with a tight-fitting lid.
6. Specimens should be sent prepaid by express, parcel-post, or stage. Avoid such unnecessary delays as may be caused by holidays and week-ends.

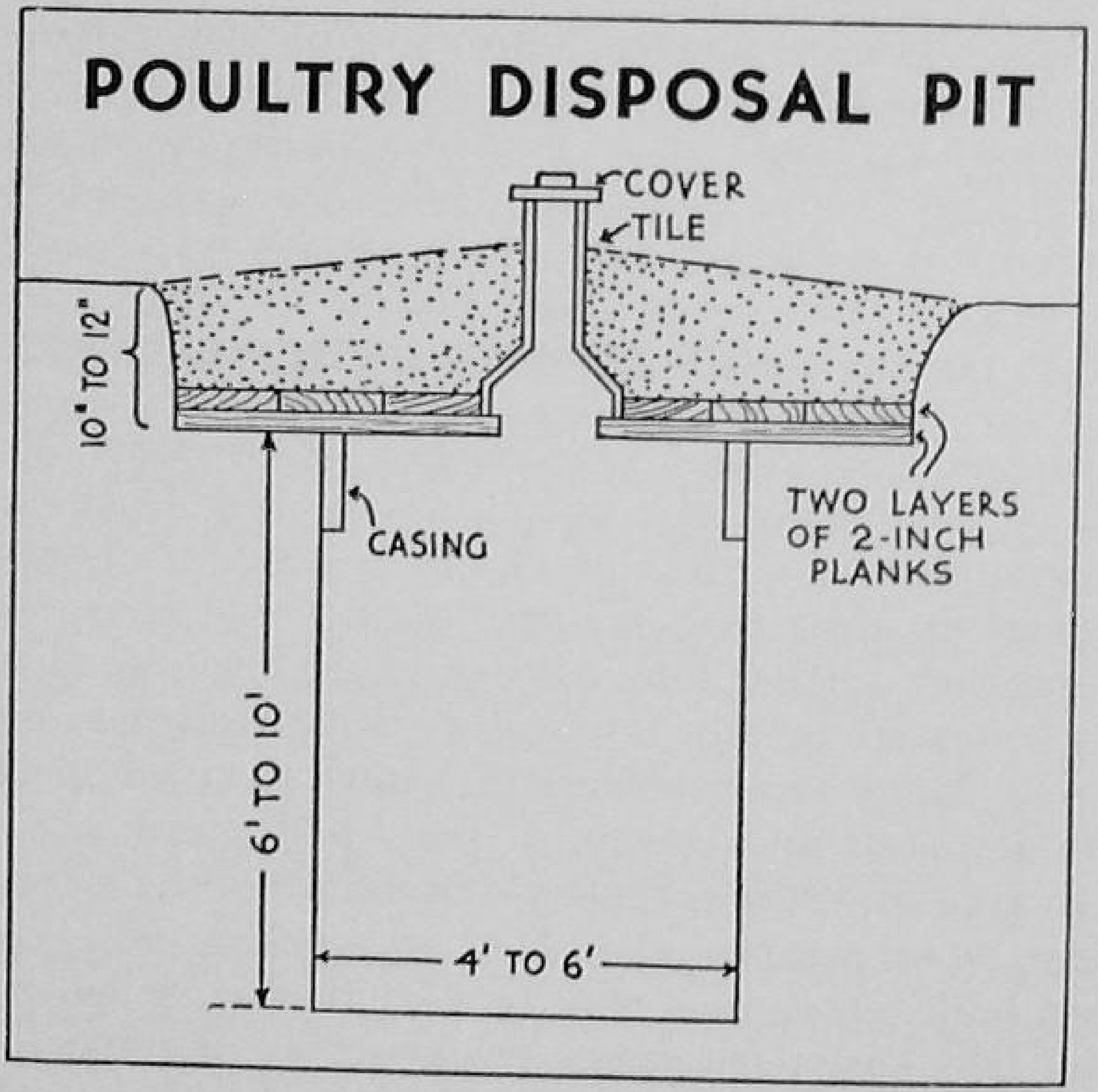


FIG. 144.—A deep, covered pit such as the one shown here simplifies the problem of disposing of dead fowls. (*Courtesy of Everybodys Poultry Magazine.*)

It is also important to send along a description of the flock giving the total number and age of birds in the flock, the number affected, how long the disease has existed, what the death loss has been, what the specific symptoms are, together with a brief description of the housing, feeding, and management methods in use. All of this can be helpful in arriving at a correct diagnosis.

COMMON DISEASES OF CHICKS

Poultry diseases may properly be classified and discussed on the basis of cause, *e. g.*, bacterial, virus, protozoan, and the like, but

the poultryman is usually confronted with the disease first and the cause later—after a diagnosis has been made. For convenience, they will be discussed here as diseases of chicks and diseases of hens, with parasites as a third classification.

Pullorum Disease.—Probably more has been written about this disease than about any other infection in poultry and no doubt more flock owners are familiar with it than with any other ailment, with the possible exception of colds. Under the provisions of the National Poultry Improvement Plan, millions of hens are tested every year for the purpose of detecting reactors which are the means of transmitting the disease to a new generation of chicks.

The cause of the disease is the microörganism *Salmonella pullorum*. In baby chicks, the disease takes the form of an acute, highly fatal septicemia, and most of the deaths occur during the first two weeks after hatching. In female chicks which survive, the organism frequently becomes localized in the ovary so that eggs laid by such individuals are very likely to be infected. After three weeks in an incubator, under conditions which are almost ideal for bacterial growth, the chicks which hatch from infected eggs are literally teeming with the organism, and early death is almost a certainty. Because of this peculiar method of transmission from generation to generation, elimination of the carrier hens is an important step in controlling the disease. The agglutination test, applied by mixing antigen with a drop of blood under field conditions, or with a small amount of blood serum in the laboratory, is the accepted means of identifying reactors. It is important to use an antigen which will show a reaction with the known variant strains, as well as with the standard strain of *S. pullorum*.

Because the disease is so readily spread from chick to chick at hatching time, it has become common practice to fumigate incubators as a precautionary measure. Either the potassium permanganate or the cheesecloth method may be used. The following practical recommendations are taken from Bulletin 416 of the Kentucky Station entitled "Effect of Formaldehyde Fumigation on Mortality of Chick Embryos."

1. The incubator and eggs should be clean and should otherwise conform to the best practices in sanitation.
2. Fumigation at high concentrations should not be made during the first three days of incubation because the embryos are then most susceptible to formaldehyde.
3. Eggs in the separate hatching compartments of an incubator should be fumigated on the eighteenth to twentieth days of incubation.
4. Eggs may be fumigated at time of hatching, but in no case should fumigation be delayed until the chicks have dried.
5. The formalin should be standard 40-per cent, commercial grade. It should be stored in a well-stoppered bottle.

WARNING: Do not permit formalin to come in direct contact with the hands, for it may cause serious skin trouble. Wear rubber gloves when handling it.

6. Potassium permanganate should be kept in a colored bottle or moisture-proof container.
7. Just before fumigation the humidity in the incubator should be raised to 92° to 94° F. wet-bulb reading. The fumigation should be performed at normal operating temperature.
8. Fumigation by the permanganate method requires the following items:
   (*a*) Measuring graduate or bottle for the formalin.
   (*b*) Small balances or standardized measure for the permanganate.
   (*c*) Large earthenware or enameled dish for combining formalin and permanganate. A large enameled wash basin or cooking utensil may be used.
9. Effective germicidal fumigation for pullorum organisms by the permanganate method requires about 35 cc. of 40-per cent formalin and 17.5 grams of potassium permanganate per 100 cubic feet. Converted to the standard usually employed by hatcherymen, this proportion is equivalent to 1.2 fluid ounces of formalin and 0.6 ounce permanganate per 100 cubic feet.
10. The dish should be placed on the floor of the incubator (or in the intake air channel), the permanganate placed in the dish, and the formalin poured over the permanganate.
11. Ammonium hydroxide may be used after fumigation to shorten the period in which the disagreeable odor of formaldehyde is present. Some reduction in embryo mortality may occur with its use.
12. Control of mushy-chick disease requires two to three times stronger fumigation than the control of pullorum. Seventy to 100 cc. formalin and 35 to 50 grams permanganate per 100 cubic feet is the concentration recommended for effective control of mushy-chick disease.

    Mortality with three times normal fumigation is not serious, and if necessary the treatment could be increased still more, provided the fumigating is done after the fourth day of incubation.
13. Fumigation by the cheesecloth method requires the following items:
   (*a*) Measuring graduate or bottle for the formalin.
   (*b*) Cheesecloth of appropriate size.
   (*c*) Small hooks, tacks, or rods, for holding cloth in place.
   (*d*) Bucket or basin in which to immerse cheesecloth in the formalin.

(e) Rubber gloves to be worn while handling the cheesecloth saturated with formalin. *Warning! Serious skin trouble may occur if formalin comes in direct contact with the hands.*

14. When the cheesecloth method is used, pieces of cheesecloth about 1 yard square should be immersed in a sufficient quantity of formalin to supply 20 cc. formalin per 100 cubic feet in incubator space. The cloth should then be hung over rods near the fan and allowed to remain for 3 hours. (This method requires approximately two-thirds the quantity of formalin needed in the permanganate method.)
15. Treatment by either method should last not less than 1 hour nor more than 3 hours.
16. If suitable measuring and weighing facilities are not available the operator should consult his local pharmacist or photographer about the weighing or measuring of the needed materials.
17. The recommendations of the incubator manufacturer should be considered in fumigating with formaldehyde.

Infectious Bronchitis.—This is popularly known as chick bronchitis or as "gasping disease." The cause is a filterable virus. The disease occurs most frequently in chicks from 3 or 4 days to 3 or 4 weeks of age, and spreads so rapidly that nearly every chick in the flock may be affected by the time the trouble is recognized. Mortality may run to 80 or 90 per cent of the affected chicks, though in some instances nearly all recover.

Adult stock is also susceptible. Mortality among hens is usually low, but egg production usually drops to zero and recovery to normal laying may take a month or longer.

The most common important mode of dissemination is probably contaminated clothing or equipment.

No effective treatment has yet been found, and the only recommendation for prevention is the strict application of general sanitation. It has not been possible to eradicate the disease from hatcheries, broiler plants, and similar establishments, without suspending operations long enough to get rid of all chickens, and to thoroughly clean and disinfect the entire premises.

Recovered birds are usually immune, but no practical method of artificial immunization has yet been found. The virus is sensitive, and difficult to work with, but some success has been obtained in the laboratory by the use of modified virus inoculation. Commercial poultrymen have frequently followed the practice of introducing a few infected or inoculated chicks into flocks of partly grown chickens so as to enable the growing pullets to develop immunity at a time when mortality is usually negligible and before there is any risk to egg production.

Since mortality among baby chicks is nearly always high, hatcherymen should brood surplus chicks in quarters which are completely separated from the areas in which incubators and hatching equipment are located.

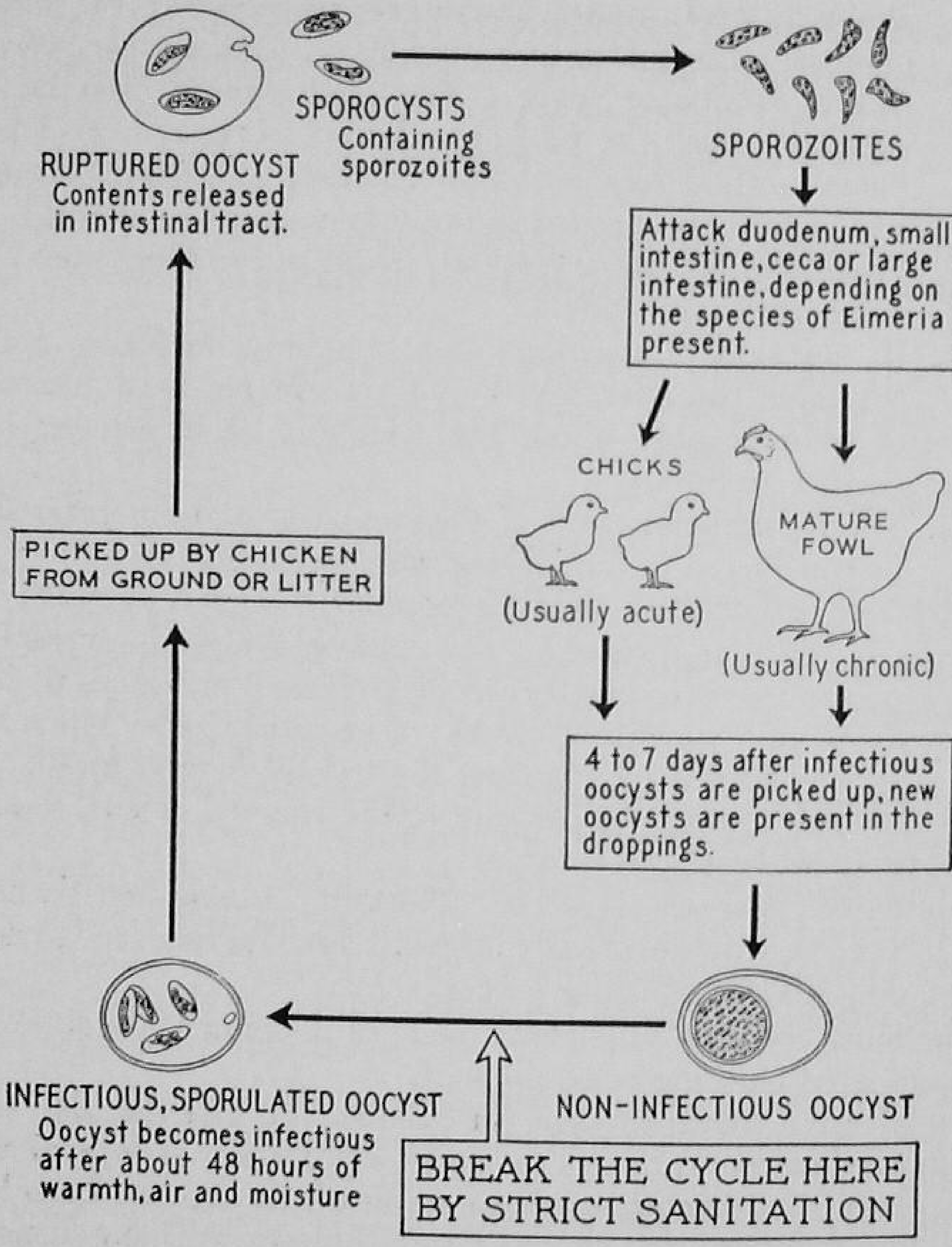


FIG. 145.—The cycle of infection in coccidiosis.

Coccidiosis.—This is one of the most widespread and destructive diseases of chickens. It is caused by various protozoan parasites belonging to the genus *Eimeria*. One species, *Eimeria tenella*, characteristically invades the lining of the ceca, producing the cecal type of the disease, while others are found in the lining of the small intestine where they cause the intestinal type. The cecal type is usually the more acute, and is often designated by poultrymen as "bloody diarrhea." Most outbreaks occur in chickens ranging from 4 to 12 weeks of age, but older chickens may become

infected. A certain degree of resistance is established by mild exposure, but resistance to one species does not protect against infection with any of the other species. Furthermore, the recovered resistant individuals may act as carriers and be a source of infection for other susceptible birds with which they come in contact for some time after their recovery.

The life cycle of the parasite is such that freshly discharged oöcysts, which pass out with the droppings, are not infective if eaten by other chickens. Within a few days, however, under suitable conditions of moisture and temperature, these oöcysts go through a process known as sporulation, after which they are highly infective. Whether eaten soon after sporulation or not for as long as several months, they become activated in the intestinal tract of the chicken and produce the characteristic infection of the cecal or intestinal lining.

Sporulated oöcysts are quite resistant, and ordinary disinfectant solutions have little effect on them. Extreme dryness is destructive to them, and so is excessive heat. It is therefore desirable to maintain dry litter in brooder houses as an aid in both prevention and control. Outbreaks are particularly common following spells of warm, wet weather which provide ideal conditions for the coccidia to develop.

The fact that some time is required after oöcysts are passed out in the droppings before they can become infective for new hosts, affords an opportunity for breaking the life cycle. If affected chickens are confined indoors, if the house is kept warm and dry, and if the litter and droppings are removed daily, so that reinfection is prevented, the disease will quickly run its course. Wire-mesh platforms to support the water and feed containers, and wire-screened roosting sections which prevent the chickens from coming in contact with the droppings are also very helpful in combating this disease. Wire panel floors may be used for the entire brooder house.

Following a mild infection, chickens normally develop a considerable degree of resistance to coccidiosis. With the introduction of practical coccidiostatic drugs, especially the newer sulfonamides, it became possible to make use of controlled infection in the widespread reduction of losses from this disease. It is most easily accomplished by brooding chicks on old litter, in which some coccidia are almost certain to be present, while at the same time using a coccidiostatic drug in the feed or in the drinking water. Sulfaquinoxaline is probably the most widely used such drug at present. The whole idea is to prevent a "runaway" infection while the chicks are developing sufficient resistance to protect themselves. Both the time and the level of feeding of the drug vary with conditions existing at the time of use.

COMMON DISEASES OF HENS

The most important diseases of hens, in terms of economic loss to the industry, are those belonging to the group caused by filterable viruses. These include fowl pox, laryngotracheitis, and the avian leukosis complex as major offenders. Fowl plague or fowl pest, and Newcastle disease, though not so common, may cause serious losses at times.

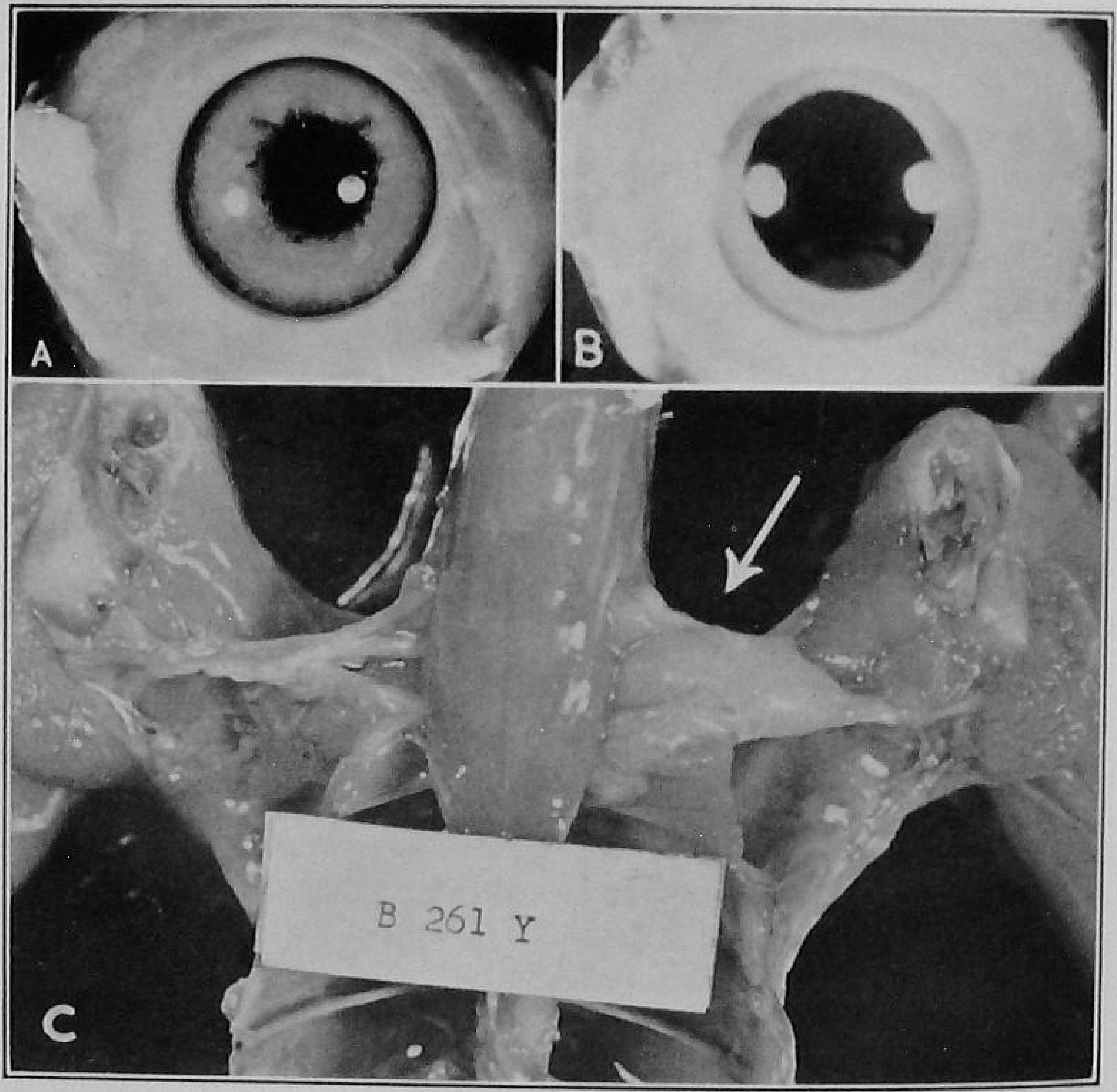


FIG. 146.—Common symptoms of the avian leukosis complex. *A*, Distorted pupil characteristic of the ocular type of the disease; *B*, a normal eye; *C*, enlarged nerve trunk characteristic of the neural form of the disease. (*Courtesy of U. S. Department of Agriculture.*)

The Avian Leukosis Complex.—This disease, known commonly as fowl paralysis, has become widespread in recent years, and has caused enormous losses to the industry. Recognition of these losses, and of the need for much more exact information concerning the disease led directly to the establishment of the U. S. Regional Poultry Research Laboratory at East Lansing, Michigan.

The avian leukosis complex takes many different forms, and this has added to the difficulties of investigators who have worked diligently to determine both cause and methods of prevention. There are six recognized types of the disease. Visceral lymphomatosis is at present the most common, and accounts for 70 to 85 per cent of all cases. In second place, accounting for 10 to 25 per cent of the cases, is neural lymphomatosis. The remaining 5 per cent of the cases are distributed among ocular lymphomatosis, osteopetrosis, leukemia or the blood form of the disease, and myelocytomatosis.

Visceral Lymphomatosis.—As the name suggests, this is a type of the disease in which the internal organs are affected. No one of the visceral organs is exempt from attack, and it often happens that several different organs are affected in the same fowl. The liver, spleen, heart, ovary, kidneys, and intestines are most frequently involved. The liver, in particular, is often greatly enlarged, and the name "big-liver disease" has often been applied to this type of lymphomatosis.

The involvement may be generalized through one or more entire organs, or restricted to local tumor areas. As in other forms of the disease, the tumors are formed by infiltration of malignant cells of the lymphocytic series into the various organs.

Neural Lymphomatosis.—This is the nerve type most familiar to poultrymen, and commonly called fowl paralysis or range paralysis. One or both legs or wings may be affected to the extent of partial or complete paralysis. The large nerves leading to the affected parts are infiltrated with tumor cells which impair their function and lead to eventual paralysis. At the Regional Poultry Research Laboratory symptoms of respiratory distress, as shown by gasping, have frequently been observed in young chickens shown to be affected with the disease. This is related to involvement of the vagus nerve. The abnormal condition often may readily be seen at post-mortem examination as enlarged, grayish watery nerves. At other times it is necessary to make use of the microscope to determine the abnormal condition.

Ocular Lymphomatosis.—This is the eye type of the disease, sometimes referred to as "gray eye" or "white eye." It is also known as iritis. The gray discoloration of the iris is often accompanied by a distortion of the pupil of the eye. In severe cases the fowl becomes blind. The change is brought about by infiltration of tumor cells. It is primarily a disease of young adults—those five to ten months of age. It is less common now than a few years ago because it is easily recognized and poultrymen have made conscious selection against it.

Osteopetrosis.—This term means hardening of the bone, and is therefore used to designate the bone type of the avian leukosis complex. The long bones of the wings and legs are the ones affected, and they become greatly enlarged, with very thick, hard walls.

The flat bones of the body become rarified, pitted and more fragile, through the loss of calcium salts, perhaps by transfer to the enlarged long bones.

Leukemia.—The fifth type of the disease is leukemia, or the blood form, and this can be of two different sorts, depending on the type of blood cell affected. If the red cells are involved, it is known as erythroblastosis. If the white cells are affected, it is granuloblastosis. An individual fowl may have either or both. The red cell type commonly appears first. If the white cell type follows, it may eventually predominate in the fowl so affected. The internal organs reflect by their color the abnormal character of the blood circulating through them. The liver and spleen are usually cherry red in color, brighter than normal.

Myelocytomatosis.—This form of the disease is mainly of academic interest up to the present time. It is characterized by small chalky white tumors which occur principally in the liver, in some other internal organs, and on the internal surface of the breast muscles along the sternum and ribs.

Prevention and Control.—Investigators are agreed that the cause of this disease is a virus or virus-like agent, and recent work suggests that there may be more than one agent involved. Transmission is accomplished through the egg, and by contact among chickens under 30 days of age. Evidence is less clear-cut about contact transmission among older chickens. Carriers may be able to transmit the infection without themselves being susceptible until conditions are just right. Thus an isolation period from hatching to 30 or 60 days of age may get by its own potential danger point without necessarily protecting the following generation of chicks. Attempts to find a "trigger" mechanism which makes a given fowl susceptible, with a view to following such a route to eventual control of the disease, have so far been unsuccessful. No diagnostic test is available, nor have attempts at vaccination produced any favorable results.

On the basis of many observations, and as a result of research at the Regional Poultry Research Laboratory, the following practices can be recommended as aids in the control of the avian leukosis complex.

1. Maintain a close flock and quarantine the premises.
2. Initiate and follow a breeding program which will make use of the most resistant families year after year.
3. Hatch chicks from these selected resistant families away from other chicks.
4. Isolate and brood chicks away from adult or other growing stock for the first 60 days.
5. If chicks are purchased, obtain them from only one source in any one year in order to reduce the chance of cross infection.

Fowl Pox.—This highly infectious disease, caused by a filterable virus, is also known as chicken pox, avian diphtheria, and sore-head. It shows up in two different forms, commonly designated as the skin or comb form, and the diphtheritic or throat form. Both types may occur in the same individual. In the skin type there are numerous small, raised, blister-like spots on the comb, wattles or face. These soon dry up and form brownish scabs. They may be scattered, and few in number, or they may cover almost the entire surface of the comb, face, and wattles. Light infection may cause little inconvenience to the fowls, but more often it is severe enough to cause loss of appetite, followed by loss in weight and a marked reduction in egg production.

FIG. 147.—Appearance of fowl pox lesions on the comb and wattles about ten days after natural infection.

In the diphtheritic form of the disease there are yellowish, raised, necrotic patches in the mouth and throat. They are firmly adherent to the mucous membrane, and may become so extensive as to interfere with eating and with breathing. The eyes are often involved, showing a watery discharge and, later a yellowish pus-like accumulation. The death rate is likely to be greater than with the skin type of the disease.

Treatment is of little value, but vaccination with egg-propagated live virus or with the older type of virus recovered from scabs grown on artificially infected fowls, furnishes almost complete protection against infection. Vaccination actually gives the chicken a mild infection which is sufficient to develop a high degree of immunity. The vaccine is most easily administered by the "stick" method while the chickens are 6 to 16 weeks of age. Vaccination should be a routine annual procedure on farms where the disease

has appeared. Pigeon pox vaccine is recommended in the case of fresh outbreaks in laying flocks.

Laryngotracheitis.—This disease, known also as chicken "flu," is a highly contagious respiratory infection which often causes high mortality. It is a comparatively new disease in the United States but it has been reported from coast to coast. The cause is a filterable virus to which chickens are extremely susceptible.

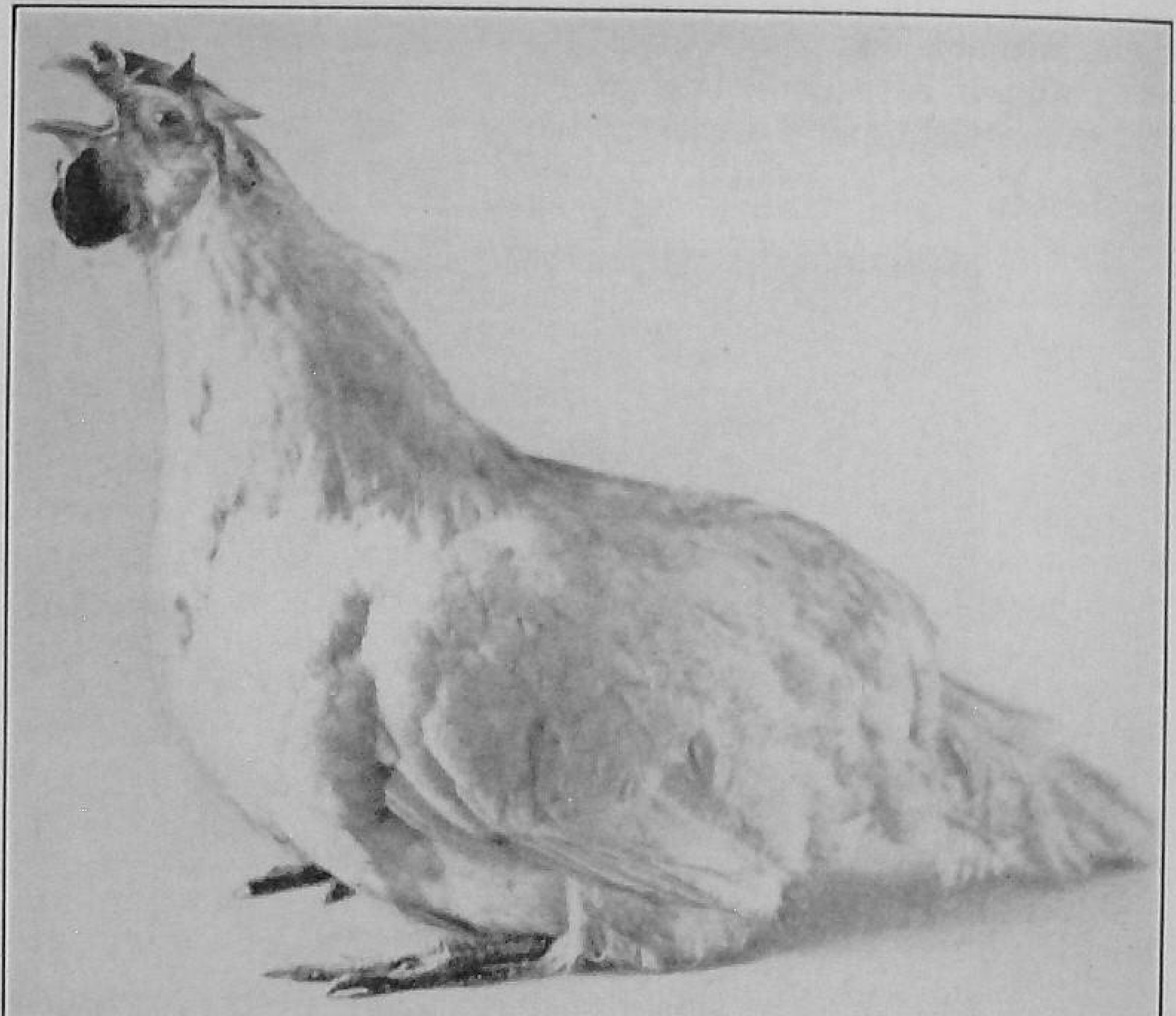


Fig. 148.—Laryngotracheitis. Characteristic position during inspiration. (*Courtesy of California Agricultural Experiment Station.*)

The outstanding and most characteristic symptom is gasping. When inhaling, the fowl extends its head and neck upward with the mouth wide open. When exhaling, the head is drawn back and lowered, with the mouth closed. Coughing, rattling, wheezing, and occasional loud cries are frequently heard, as the fowls attempt to dislodge the accumulations of mucus in the air passages.

A vaccine prepared from the membranes of artificially infected embryos or from the tracheal exudate of infected fowls, and applied to the mucous membrane of the cloaca, gives protection against later infection. Since the live virus must be used for vaccination purposes, and since it is capable of causing the disease to break

out in virulent form, great care must be taken to see that it is properly used. For this reason, vaccination is ordinarily not recommended unless the disease is prevalent in the community, or occurs regularly on the farm from year to year because of the presence of recovered carriers. If several flocks are housed on a single farm and the disease occurs in one of them, the others may be protected by prompt vaccination. When annual vaccination is practised, the usual procedure is to apply it when the new crop of chickens is 8 to 16 weeks old.

Fowl Plague.—The filterable virus which causes fowl plague, or fowl pest, is highly infectious, even in minute amounts. The disease is characterized by an extremely rapid course and high mortality. It is reported to be rather prevalent in Europe, but only two serious outbreaks have occurred in this country, one in 1925 and one in 1929. In both instances the disease was eradicated by prompt action of sanitary officials.

Since the virus is contained in the blood, intimately associated with the red blood cells, there is usually a generalized hemorrhagic condition evident at autopsy. This, together with the rapid onset of the disease and the high death rate, ranging from 50 to 100 per cent, will usually be sufficient for diagnosis. Medicinal treatment is of no benefit whatever. Prompt and complete eradication of affected flocks is essential for the protection of the entire industry. If this disease is suspected, Federal and State officials should be notified immediately.

Newcastle Disease (Avian Pneumoencephalitis).—This virus disease has been known for many years in various parts of the world, but not until the middle forties did it become of major importance in the United States. It is a highly infectious respiratory disease. In young chickens there are varying degrees of muscular incoordination, including many peculiar motions such as walking backward or in circles. In older flocks egg production commonly drops to zero within three to five days after an outbreak. When egg laying is resumed after 4 to 6 weeks, many of the eggs are abnormal in shape with rough and thin shells. Interior quality is also adversely affected. Death losses are usually low among fowls of laying age, but may range up to 25 per cent or more in chicks.

Control is possible through vaccination, but authorities differ in their recommendations as between live and killed virus, and whether the wing-web or intranasal method should be used. In areas where the disease is not too common, killed virus vaccine has been very helpful. In areas where the disease is quite general, and flocks of commercial size are close together, the tendency is to use intranasal or eye-instilled vaccination with live virus on day-old chicks, or the wing-web method with live virus at 3 to 4 weeks of age, followed in either case by a second vaccination at 4 to 6 months using the wing-web or stick method.

rarely are such feeds actually poisonous, as when they have been loaded in cars or trucks which previously were used for some poisonous substance without proper cleaning before re-use. Hundreds of suspected feed samples have been tested by feeding to young chickens and nearly all of them have proved to be harmless. Corn, barley, and wheat grown in certain limited areas in central South Dakota contain sufficient selenium to cause poisoning. Selenium from this source, fed at the rate of 15 parts per million of the total ration, caused hens to lose weight and reduced the hatchability of their eggs to zero.

POULTRY PARASITES

Chickens are subject to infestation by a large number of internal and external parasites but, fortunately, only a few of them are of sufficient importance to need special consideration. Certain ones are more important in one section of the country than in another, and some show a seasonal variation in frequency of occurrence. Some are easily kept under control by ordinary good sanitation practices, whereas others require special methods for their elimination.

Internal Parasites.—Most important among the internal parasites are the large roundworm of the small intestine, the cecal worm, the gapeworm, and the several varieties of tapeworms

The Large Roundworm.—This is the common intestinal worm, known to most poultrymen, and usually found in the small intestine. It ranges in length from 1½ to 4 inches, and in numbers from two or three specimens in a single fowl to so many that the bowel is completely filled for a distance of several inches. Prevention is best accomplished by general sanitation, including rotation of lots and ranges, and elimination of low wet areas, or damp spots around the watering devices. Such practices reduce the opportunity which chickens may have for picking up worm eggs. There is no known spray or disinfectant which is effective in killing roundworm eggs.

Tests at the Georgia station, involving 24 lots of broilers over a two-year period, showed that normal sanitary management procedures without the use of any anthelmintics were sufficient to prevent any serious infestation with roundworms. These broilers were grown in pens known to have been contaminated, half on dirt floors and half on concrete.

Treatment of affected fowls is best done individually rather than on a flock basis, but on a well-managed farm should not be necessary. Carbon tetrachloride is the recommended drug for removing the large roundworm. The dosage rate is 4 cc. per kilogram of body weight, but an unfavorable effect on egg production must be expected following its use.

The Cecal Worm.—The cecal worm of chickens is very small, not over ½ inch in length, and grayish-white in color. It is frequently found in great numbers in the ceca, where it produces severe inflammation. The life cycle of this parasite is practically identical with that of the large roundworm, and therefore the same methods of prevention and control are effective, namely, general sanitation, rotation of lots and ranges, and strict separation of young and old stock.

Fig. 150.—Section of intestine showing roundworms protruding from a cut end. *(Courtesy of California Agricultural Experiment Station.)*

Treatment should not be necessary in well-managed flocks, but the drug phenothiazine has been found to be effective in killing and expelling the worms. The dosage is ½ gram per chicken, and flock treatment has been reported to be as effective as individual treatment.

The Gapeworm.—This parasite has become of much less significance as artificial brooding has replaced natural brooding, and is probably completely unknown to many flock owners. At times, however, and in certain sections of the country it is still troublesome. It inhabits the trachea or windpipe and when present in large numbers interferes with breathing to such an extent that the chickens gape for air. Hence its name. It is primarily a parasite of young chicks, and is rarely of any consequence in older fowls.

Prevention is effectively accomplished by general sanitation,

and by raising young chickens on ground where no gapeworm-infested chickens have been allowed to range. Treatment, if required, is best accomplished by the use of barium antimonyl tartrate, a comparatively new drug, as an inhalant. The chicks are confined in a small box or other enclosure into which the powder (which must be fine enough to pass through a 100-mesh screen) is blown three times at 5 to 10 minute intervals. The amount of powder required for a three-dose treatment is one ounce to about 8 cubic feet of space.

Tapeworms.—These parasites are flat, segmented, ribbon-like worms, which vary in size, depending on the species, from those so small as to be barely visible, to types which are as much as 10 inches long. So far as is known, all tapeworms require an intermediate host for the completion of their life cycle, and this is the key to

FIG. 151.—Wet spots on the range can be avoided by placing drinking fountains over a pit filled with coarse gravel. (*Courtesy of Poultry Tribune.*)

their prevention and control. If chickens can be so managed that they have no opportunity to eat any of these intermediate hosts, which consist of various beetles, flies, and slugs, there is no possibility of their becoming infested with tapeworms. Prevention is therefore the logical method of control.

Frequent removal of poultry manure to prevent it becoming a breeding place for flies is important. If roosting racks are used, the manure beneath them should be treated regularly to keep down the fly nuisance. Slugs may be eliminated, or their numbers greatly reduced by the use of certain poison baits when necessary. Earthworms, which may serve as mechanical carriers of the eggs of various parasites, can be kept under control by eliminating wet areas, and seeing that the ranges are well drained throughout.

More than 200 different substances have been tested in attempting to find a medicinal agent which would be effective for the removal of tapeworms from chickens, but none has been demonstrated to be of any real value. It is true that several different drugs will cause quantities of segments to be detached and removed, but the heads of the tapeworms remain attached to the wall of the intestine and promptly regenerate so that the infestation is soon as bad as before the treatment was given. In the light of experimental evidence so far available, no dependence whatsoever can be placed on any known treatment designed to rid chickens of tapeworms.

FIG. 152.—Inside of a hen's intestine showing attached tapeworms. (*Courtesy of California Agricultural Experiment Station.*)

Parasitologists continue to search for effective methods of tapeworm removal, and it is entirely possible that they may yet be successful. Encouraging reports have recently appeared concerning the effectiveness of certain tin compounds and of hexachlorophene. Certain phenyl mercuric compounds have also been shown to have some value against tapeworms. But until more convincing experimental evidence is available, flock owners should continue to apply the best known sanitary measures in preventing tapeworm infestations.

External Parasites.—The control of external parasites is an important practical problem wherever fowls are kept. In most instances control measures are comparatively simple and effective, but if they are omitted the loss caused by the parasites may be very serious.

Lice.—Several different kinds of biting and chewing lice infest chickens. They are permanent parasites in the sense that they live and reproduce on the body of their host. Furthermore, there is a tendency for each species of lice to prefer a certain location on the body of the fowl. Among their special characteristics are flattened bodies, legs which are peculiarly well fitted for clinging to skin and feathers, and a remarkable ability to move about so as to remain out of sight among the feathers.

The three common species of chicken lice are the head louse, the body louse, and the shaft louse. Others are seen occasionally, but cause much less damage. Since one method of treatment may be used for all, the exact species present is of little consequence to the flock owner.

Among the several possible methods of treatment, the most effective is the use of sodium fluoride either as a dust or as a dip. This material is available as a white powder which, in the commercial grade is about 90 per cent pure. It is poisonous to animals or to humans if taken internally and must be used with care, and properly labelled as a poison. To insure complete control, with a minimum chance of immediate reinfestation, it is absolutely essential that every chicken on the farm be treated. If two or three lousy hens are missed, the flock may be badly reinfested in a short time.

When used as a dust, the powder is best applied to each fowl by the pinch method in order to waste as little as possible, and to reduce to a minimum the amount of irritating dust in the air. The fowl is grasped by the base of the wings and several pinches of powder placed among the feathers on different parts of the body. If a large number of fowls is to be treated, the operator should protect his nose and throat by wearing a respirator or a wet sponge over the nose and mouth, and should be careful to keep the powder out of his eyes.

Dipping is faster, especially when a large flock is to be treated, and less of the powder is required to treat a given number of fowls. Treatment should be given on a warm day to prevent chilling the fowls. Workers in the U. S. Department of Agriculture who developed the method recommend adding a rounding tablespoonful of the powder to each gallon of water. Each fowl is then grasped by the base of the wings and lowered into the solution while the feathers are ruffled to insure penetration of the material to the skin. The head is then ducked under once or twice, the fowl lifted out and allowed to drain for a few seconds, and released. Fowls can be treated by this method at the rate of about 150 in an hour.

A more convenient method of control is fumigation with Black Leaf 40, a commercial preparation of nicotine sulphate. The material is applied to the top of the perches just before dark, at the rate of 8 ounces to each 100 feet. It is not effective in cold weather because too little volatilization takes place at temperatures

below 60° F. Since this material does not affect the eggs of the parasites, it is necessary to give a second treatment in about ten days. Nicotine sulphate is extremely poisonous, if taken internally, and must be used with care.

Nicotine sulphate is also effective when applied directly to the skin of infested fowls—one drop an inch below the vent and one on the back of the neck.

One of the newer fumigants, hexachlorocyclohexane (HCCH), has been shown to be highly effective against poultry lice. It can be applied in either paint or spray form, and only the roosts need to be treated. The material is effective in concentrations no greater than 0.5 per cent of the gamma isomer.

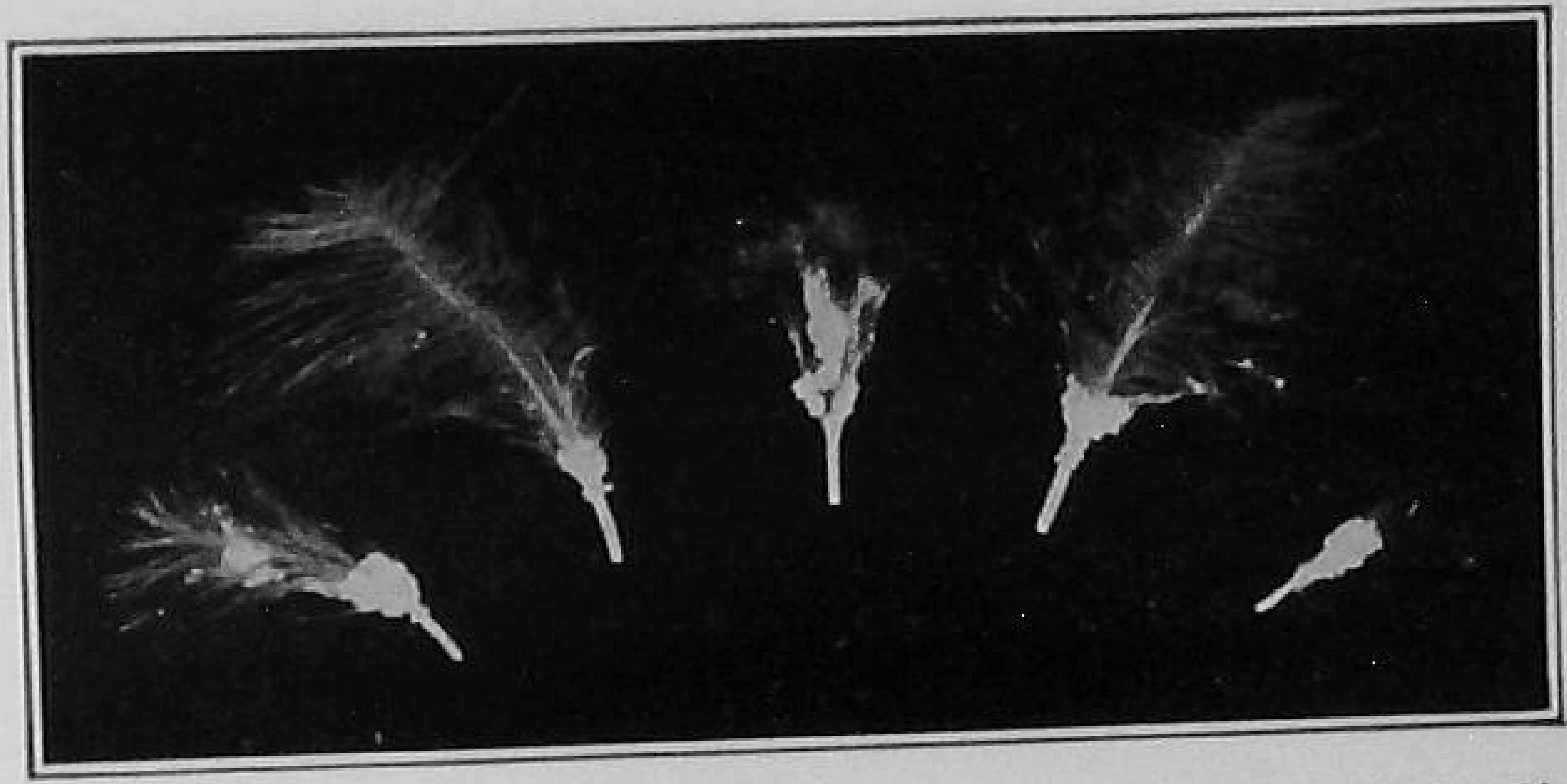


Fig. 153.—Eggs (nits) of the common large louse, attached to the shafts of body feathers.

Roost Mites.—The common roost mite is a familiar pest in all parts of the country. The habits of this parasite are quite different from those of lice. The mites spend most of their time in cracks and crevices about the house, especially the roosts and roost supports, going on the fowls mostly at night. Since they are blood-sucking parasites, they are especially destructive, and they cannot be killed by the methods ordinarily used for body lice. Strong contact insecticides are necessary. One of the most effective materials is high-grade anthracene oil, commercially available as carbolineum. Most wood preservatives with a creosote base are also effective. It is important to reach the porous surfaces, including any cracks and crevices, of the roosts and roost supports. Workers at the Florida Station have reported effective control of the mites by sprinkling finely divided sulphur freely about the house, including the roosts, droppings boards, litter, and nesting material.

Hexachlorocyclohexane (HCCH), as recommended for the control of body lice, is also effective against the roost mite. Thorough cleaning and scraping of droppings boards, and careful thorough spraying are necessary for the control of this pest.

Scaly-leg Mites.—These mites are so named because they are responsible for the condition known as scaly leg in fowls. Scaly leg is rarely seen on well-managed poultry plants but it may become serious when fowls are kept for long periods under insanitary conditions. Control is most effectively accomplished by disposing of all mature fowls, giving the house and adjacent yard a thorough cleaning, and then restocking with young pullets. If treatment is to be practiced, it is necessary to find some material which will penetrate beneath the scales of the shanks in order to reach the minute parasites. It must be strong enough to kill the mites without being too irritating to the fowls. Soaking the shanks three times at intervals of 2 to 4 weeks in a 0.5 per cent solution of sodium

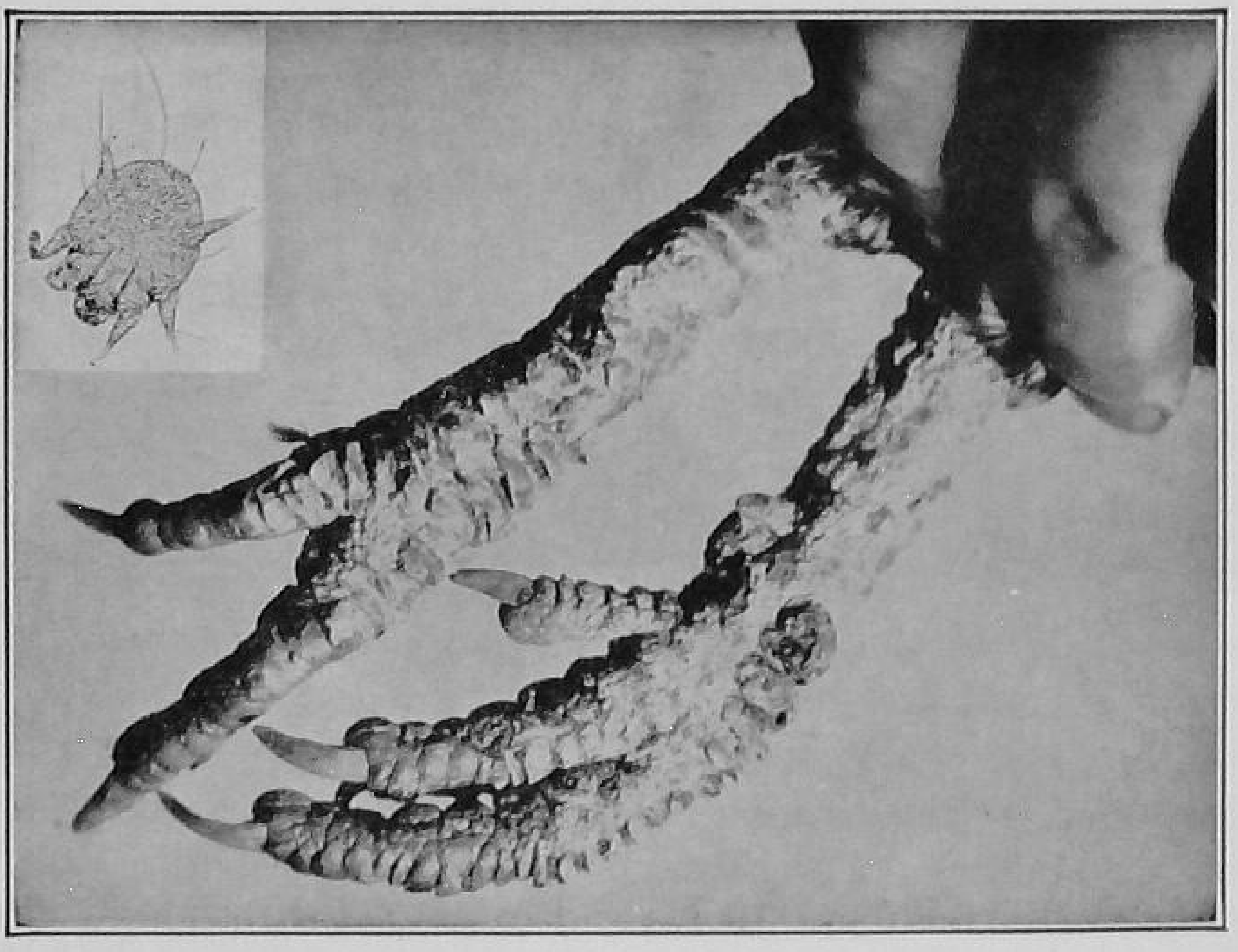


FIG. 154.—The condition known as scaly leg. Inset shows the larval stage (greatly enlarged) of the mite which causes the trouble. (*Courtesy of Illinois Agricultural Experiment Station.*)

fluoride is said to be effective, as is also dipping in a mixture of 1 part kerosense and 2 parts raw linseed oil. Since the mites spread readily from fowl to fowl, treatment of the roosts as for the roost mite is also important.

Northern Fowl Mites.—The northern fowl mite, also sometimes called the feather mite, is a serious pest. Since they may reproduce either on the fowls or in the nests, single treatments are not always sufficient for complete eradication. They are most commonly found around the base of the tail and around the vent, and frequently they prefer male hosts. Their feeding habits are such as to cause the formation of large scabs which spoil the appearance of dressed carcasses. Outbreaks occur sporadically, and often are rather

severe before they are discovered. They are sometimes found by reason of the dirty appearance which they give to the plumage of white fowls.

Several methods of control are effective. One of the best, especially in cold weather, is to dust each fowl thoroughly with finely divided orchard spray sulphur. The nests should also be liberally dusted. Since English sparrows harbor this parasite, nests near the poultry house should be destroyed and burned.

Nicotine sulphate applied to the skin, one drop below the vent, one on the back of the neck, and one under each wing, has been found highly effective in controlling these mites.

Fowl Ticks.—The fowl tick is common in the southern part of the country and is a serious pest. It is a powerful blood sucker, and its habits are similar to those of the roost mite. The same general methods of control are recommended, but they must be more rigorously applied. Carbolineum is the material considered to be most effective, though crude petroleum and creosote oil may also be used. It is necessary to do a very thorough job of cleaning, burning all litter and trash, and even treating nearby trees as well as other outbuildings to which the chickens have access, in order to accomplish complete control. In the case of heavy infestations it may be necessary to give two or three treatments before the pests are eradicated.

Sticktight Fleas.—These parasites are common throughout the southern states, from Florida to California. They attack dogs, cats, and rats, but find chickens an ideal host. They attach themselves to the comb, face, wattles and earlobes in large numbers, and since they are voracious feeders they cause serious injury. Eggs laid by the adult females fall to the floor or ground, and the remainder of the life cycle, through larval and pupal stages to adult is passed there. Control measures must include treatment of the floor of the poultry house and nearby infested soil, as well as the affected fowls.

According to reports from the California Station, sprinkling the yards two or three times weekly for a short period will greatly reduce the breeding of these pests, since they cannot thrive in damp surroundings. The effectiveness of the treatment is increased by scattering salt freely about the yards before wetting the soil.

The Florida Station has reported that complete control was secured by a combination of feeding 5 per cent of commercial sulphur flour in the mash for a period of three weeks and dusting sulphur on the surface soil and in the poultry house at the rate of 2 pounds for each 100 square feet. Neither feeding nor dusting alone was effective.

Affected fowls may be treated by the application of 2 per cent carbolic ointment, or tincture of iodine. Great care must be taken not to get either of these materials into the fowls' eyes.

All litter, manure, and other refuse from the house should be burned or spread on distant fields where it can be promptly plowed under. Otherwise the flea larvæ will continue to develop and will soon be ready to attack any dogs, cats, or humans in the neighborhood.

Rat control is especially important in preventing flea infestations in the poultry flocks.

Other External Parasites.—Various other parasites occasionally become a nuisance to poultry flocks, and special control methods are sometimes necessary. Chiggers or "red bugs," common bed bugs, Mexican chicken bugs, black flies, and depluming mites may cause trouble at times, but they are usually not a problem on well-managed farms and ranches where sound sanitation practices are continuously followed.

DISINFECTANTS AND THEIR USE

Disinfectants are substances which have the power to kill microorganisms. They are very valuable materials to use under certain conditions, but in good poultry management they are always secondary to scrupulous cleanliness. Not only is cleanliness more important as a means of preventing losses from disease, but it is an essential preliminary to effective disinfection. The action of most disinfectants is greatly retarded in the presence of accumulated organic matter of any kind. Furthermore, the use of copious amounts of water will both wash away infective organisms and dilute them to the point that they are much less dangerous.

Direct sunshine is an effective germicide, and it can often be used to advantage for equipment which is portable and so constructed that it can be fully exposed to the sun's rays.

When disinfection is necessary it is important (1) to do a thorough job of cleaning first, (2) to apply the disinfectant while it is warm or hot if possible, (3) to use it liberally and to apply it thoroughly, and (4) to allow plenty of time for the disinfectant to act.

Steam applied under pressure is probably the most effective of all disinfectants, but it is not available under average farm conditions. Boiling water is also effective, and frequently can be used on the farm.

Chlorine is a good cheap disinfectant that may be used freely. The addition of a wetting agent or detergent when using chlorine solutions will increase their effectiveness.

Quaternary ammonium compounds are very effective against bacteria, but not so satisfactory for viruses. Time is the important factor in cleaning up after a virus infection. Material contaminated with a virus may become safe in as short a time as three weeks after thorough cleaning if moisture and temperature conditions have varied during that period.

Formaldehyde gas is effective in spaces which can be tightly closed, especially if the air is warm and moist. Directions for the use of this material for incubator fumigation have been given in connection with the discussion of pullorum disease.

Common lye (sodium hydroxide) is a powerful disinfectant, especially if applied in a solution of hot water. A 2 per cent solution is made by adding 1 pound of lye to 6 gallons of hot water. Lye must be kept in tightly closed containers because it very soon becomes inactive on exposure to the air.

Fig. 155.—A kerosene-fired steam sterilizer which can be used to good advantage on commercial poultry plants. (*Courtesy of Illinois Agricultural Experiment Station.*)

Saponified cresol solutions are prepared by several different manufacturers and are usually available through local drug and supply houses. The commonly recommended dilution is 4 ounces to a gallon of water. Soft water should be used if available, because the cresol solutions do not mix so readily with hard water.

Since most disinfectants are very irritating, it is important to protect the eyes, face, and hands from contact with the solution being used.

CHAPTER 13

MARKETING POULTRY PRODUCTS

When poultry keeping is expanded beyond the needs for home consumption, and is made a matter of producing chickens and eggs for profitable sale, some form of marketing becomes necessary. Marketing involves buying and selling, and the physical movement and distribution of poultry and eggs between the point of production and the point of consumption. It includes certain phases of production, transportation, storage, financing and merchandising. It also includes the sorting of products on the basis of physical characteristics and quality, *i. e.*, grading and standardization. A certain amount of processing is done before eggs and poultry reach the final consumer. In some cases this involves the actual manufacturing of a new product, but in others it is more or less incidental to the necessary preparation of the product for consumption.

The expense of carrying out these various activities and functions makes up the cost of marketing. With the growth of modern processing, transportation and storage facilities there has developed an extensive and complicated system for the purchase, distribution and sale of poultry products. A complete discussion of the many agencies involved in this system is beyond the province of this book. Instead, we shall follow the products to see what happens to poultry and eggs from the time they are ready to leave the farm until they reach the consumer.

The Marketing Problem.—The ultimate objective of the marketing process in connection with poultry and eggs, because of their perishability, is to put them in the hands of consumers with their original quality unimpaired. In practice this is seldom accomplished in a full and complete sense except where direct marketing from producer to consumer is involved. It will be the purpose of this chapter, however, to emphasize that objective and to point out the ways in which it may most nearly be attained.

Seasonal Distribution of Production.—One of the important phases of the marketing problem arises out of the fact that the movement of both eggs and poultry to market is of a seasonal nature.

Total egg production is much more nearly uniform from month to month than it was even ten years ago, but it is still true that about 40 per cent of the yearly egg crop is produced in the four months of March, April, May and June. Of total shipments of dressed poultry to the four principal terminal markets, New York, Chicago, Phila-

delphia and Boston, over 40 per cent are received during the three months of October, November and December. Live poultry receipts have been fairly uniform from month to month in recent years.

TABLE 33.—CONSUMPTION OF POULTRY PRODUCTS PER PERSON IN THE UNITED STATES, 1946–1950, AS REPORTED BY THE U. S. DEPARTMENT OF AGRICULTURE

Year	*Number of eggs*	*Pounds of chicken*	*Pounds of turkey*
1950 . . .	394	26.9	5.0
1949 . . .	381	25.5	4.2
1948 . . .	386	23.1	3.6
1947 . . .	379	23.6	4.5
1946 . . .	374	25.4	4.5
5-year average	383	24.9	4.4

FIG. 156.—A view of Chicago's South Water Market. (*Courtesy of U. S. Egg and Poultry Magazine.*)

Geographical Distribution of Production and Consumption.—The wide distribution of poultry flocks does not coincide with the geographical distribution of population. Thus New York, with 10 per cent of the population, has less than 4 per cent of the chickens, while Iowa, with less than 2 per cent of the population, has 7 per cent of the chickens. In general, the deficit production areas are those in which there is the greatest density of population and, except for variation in food habits, the greatest quantities of poultry and eggs are needed where the most people live. This means that the "egg stream" of the country flows east toward the centers of population.

New York City, because so many people live in and adjacent to it, is the most important egg and poultry market in the country.

Commercial broiler production, in contrast to egg production, has been highly developed in eastern areas close to the centers of population. Furthermore, as indicated in the opening chapter, the concentration of poultry and egg production per square mile is much greater in the eastern states than elsewhere.

The Maintenance of Quality.—Because of the seasonal nature of poultry and egg production, and because of the differences in geographical distribution of poultry and human population, the matter of maintaining the quality of poultry products during the time that elapses between their production and their delivery to the final consumer is of great importance. Its successful accomplishment requires that every individual who has anything to do with the marketing of eggs or poultry shall be "quality conscious," and interested in reducing the loss of original quality to a minimum. The advantage gained from strict attention to production factors that affect quality may be quickly lost if the products are not properly handled after they leave the farm.

MARKET EGGS

Although a single terminal market, such as New York City, may receive eggs from as many as forty different states in a single year, most of its receipts come from seven states. For the four principal markets combined, 94 per cent of the receipts of shell eggs in 1950 came from the eleven states listed in Table 34, and over 70 per cent came from the five states of Iowa, Minnesota, Pennsylvania, Wisconsin and New York.

TABLE 34.—STATES SENDING AS MANY AS 100,000 CASES OF SHELL EGGS TO ANY ONE OF THE FOUR MARKETS IN 1950. AS REPORTED BY THE U. S. DEPARTMENT OF AGRICULTURE.

State	*New York*	*Chicago*	*Philadelphia*	*Boston*	*Total 4 markets*
			(1000 cases)		
Iowa	930	1,081	124	117	2,252
Minnesota	479	904	251	10	1,644
Pennsylvania	841	—	652	—	1,493
Wisconsin	13	1,339	2	5	1,359
New York	1,178	1	7	28	1,214
New Jersey	657	—	75	—	732
Illinois	86	427	69	38	620
Massachusetts	7	—	—	356	363
New Hampshire	1	—	—	260	261
Maine	—	—	—	246	246
Indiana	153	62	3	5	223
All other	243	148	141	150	682

Similarly, the product from a single state or area may be widely distributed over the country, but the tendency is for the bulk of shipments from a given state to go to a single terminal market. Broilers furnish an example. During the year beginning with October, 1949, some 400 million pounds of broilers were marketed from the Delmarva area. Although they were shipped to 37 different states, almost 50 per cent went to New York, and another 30 per cent were distributed among the four states of Illinois, New Jersey, Pennsylvania and Nebraska.

For the majority of flock owners, eggs furnish the most important source of income, poultry meat being secondary. It will usually pay the poultryman, therefore, to give particular attention to the matter of producing eggs of high quality and to market outlets that recognize quality and are willing to pay for it.

Quality the First Essential.—The demand for high-quality eggs is growing, and is likely to continue to grow for some time to come. If producers are to receive the full benefit from this growing demand they must know what constitutes high quality in eggs, how such eggs can be produced, and how they should be marketed.

Eggs are among the most delicate and perishable food products, are subject to rapid deterioration, and are easily affected by unfavorable surroundings. In food value, flavor and general attractiveness, they are better when first laid than at any later time. Because consumers are quick to discriminate against poor eggs, it is important not only that the right kind of eggs be produced, but that they be so handled as to reach the consumer with the least possible loss of their original quality.

Consumer Preferences.—The consumer is the final judge of what constitutes quality in eggs. Many consumers are highly discriminating in this respect, and are willing to pay well for the assurance of being able to secure a particular grade or quality of eggs.

Records obtained from 2404 families in six Pennsylvania cities in 1926 showed an average annual per capita consumption of 28.7 dozens of eggs, or slightly less than 1 egg a day for each person. Nearly one-half of the families had no preference as to shell color, except in the city of York, where 53 per cent preferred brown eggs. In the other cities the families that had a preference were about equally divided between white and brown eggs.

A study made by the Illinois Station involved 48 retail stores in the city of Chicago. Observations were made over a period of one year. In 24 of the stores five grades of eggs in addition to the regular store grades were carried throughout the test. The price of the best eggs was from 10 to 17 cents a dozen above that of the lowest of the five grades. Of the consumers who purchased the best grade, 78 per cent stated that they did so because they were the best eggs obtainable. Of those who bought eggs of the lowest grade, 83 per cent reported that they did so because of price. It

is significant that at no time were there enough eggs of the top grade to supply the demand for them, in spite of the premium price.

The study included a survey of 11,443 housewives in Chicago city and suburban territory, in which information was obtained as to preferences for white and brown shells, and pale, medium and orange yolks. Nearly one-third of the persons interviewed had no preference for either white or brown shells. Those in suburban territory who expressed a preference were about equally divided between white and brown shells. In the city proper, however, 45 per cent of those interviewed expressed a preference for eggs with white shells. It appeared that this preference was based on the fact that white color was associated with good interior quality. Judging from other information obtained in connection with the study, it seems safe to conclude that purchasers of eggs are first of all concerned with interior quality, and that the color of shell is of little importance except as they have come to associate it with a particular quality as the result of experience.

Although about 60 per cent of the persons interviewed had some preference for yolk color, they were about equally divided as between pale and orange yolks, and only about one-third of those who had a preference stated that they would be willing to pay a premium in order to obtain eggs of that particular yolk color.

In a somewhat similar study made in New York City, 10,358 consumers were asked to express their preference for eggs with light, medium, and dark yolks, and with brown and white shells, that were offered for their inspection. Slightly more than one-third expressed a preference for light yolks, one-fourth for dark yolks and one-fifth for yolks of medium color, while one-fifth had no preference. Slightly less than one-half of the consumers interviewed expressed a preference for white shells, and about one-fourth preferred brown shells. The others had no preference. These results indicate that consumers in New York react in much the same way as those in Chicago, and that assurance of interior quality is what they really desire.

The Rhode Island Station has reported the results of a study based on personal visits to nearly 600 housewives in Providence, R. I., in 1928 and again in 1932. The percentage of persons who expressed a preference for shell color in the two years was found to be, for brown eggs 43 and 46, and for white eggs 18 and 13, respectively. The others had no preference. In 1928 it was found that 43 per cent of those interviewed preferred light or medium-colored yolks, while 36 per cent preferred dark yolks; but in 1932 the corresponding percentages were 75 and 12.

In the 1932 survey a question asked was, "What factors in eggs are worth an extra price to you?" Large size was mentioned by 25 per cent of the housewives, and the weighted average premium which they were willing to pay was nearly 4 cents. Freshness was

worth a weighted average premium of 5.4 cents a dozen to 23 per cent of those interviewed. No other factor was mentioned by as many as 10 per cent of the housewives.

Studies of consumer buying habits with reference to eggs have also been carried out by the U. S. Bureau of Agricultural Economics in Boston, New York, Newark, N. J., and Washington, D. C.

Measures of Egg Quality.—Quality in eggs, with reference to food value or market desirability, is measured: (1) by external appearance; (2) by candling; and (3) by odor, flavor and physical character of the opened egg. For the most part, these measures give only a gross picture that is sufficient for trade purposes. Exact measures of quality, in the scientific sense, have been almost totally lacking, though considerable progress in that direction has recently been made.

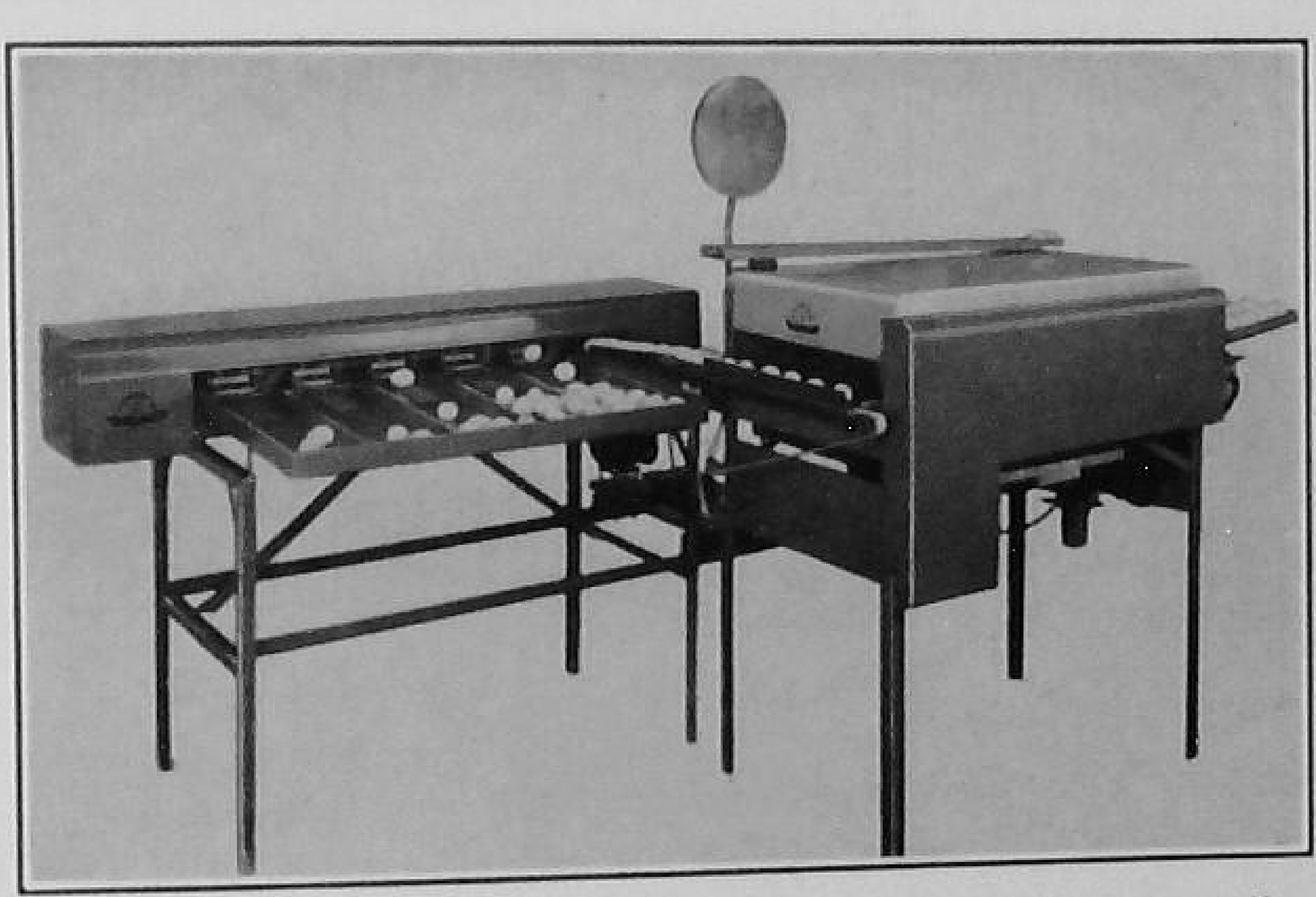


FIG. 157.—A combination dry egg cleaner and grader which automatically sorts eggs according to weight. This machine has a capacity of five cases an hour. (*Courtesy of Otto Niederer Sons, Inc.*)

External Appearance.—Under this heading may be mentioned size, shape, shell color and texture, cleanliness and uniformity of eggs within a given sample or lot. While small eggs of high interior quality may be worth more than large eggs of low quality, it is none the less true that size is a most important factor in determining the price received for eggs in any market. The standard size is 2 ounces each, or 24 ounces to the dozen, and it has become customary to refer to 22, 23, 24 or 26-ounce eggs when what is meant is the weight of a dozen. Eggs weighing up to 26 ounces to the dozen may sell at a premium over 24-ounce eggs, but extremely large eggs (28 ounces or more to the dozen) are not wanted because of the greater danger of breakage when handled in ordinary containers, and the extra expense involved in handling them in special

packages. These objections do not, of course, apply to a strictly local market where extra size may occasionally be made the basis of extra premiums. Eggs weighing less than 24 ounces to the dozen will have to be sold at a discount in most, if not all markets, during a large part of the year.

Workers at the Massachusetts Station studied the relation between egg quality and price in retail stores in Springfield, Worcester and Boston. The most definite and significant relationship found was that prices were directly related to weight under all conditions. Weight was most important, both relatively and actually, in August, each additional ounce per dozen causing an increase of 4.5 cents a dozen in price. The corresponding figures for April and November were 2.4 cents and 3.2 cents, respectively.

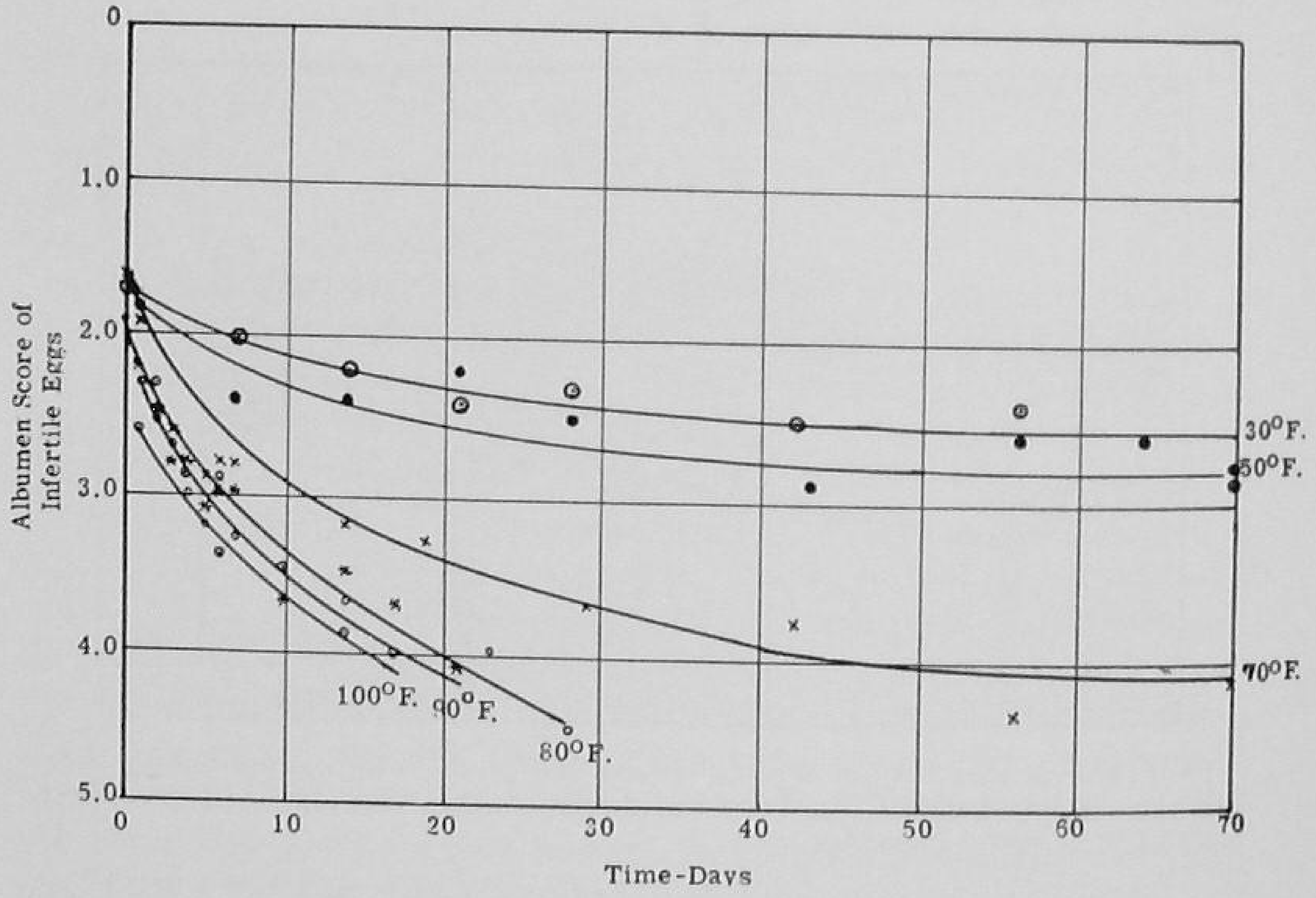


FIG. 158.—Showing the effect of temperature on change in egg quality as measured by the albumen score. (*Courtesy of Missouri Agricultural Experiment Station.*)

Shape is not often of great importance, and in any event it is easily controlled by selection. It should be remembered, however, that short, round eggs do not make the best appearance in an ordinary case or carton, and that long eggs are much more likely to be broken during shipment than are eggs of normal shape.

Shell color is, in the main, a breed characteristic, though there is often wide variation among individual hens in a particular flock when all are of the same breed and variety. If white eggs are to sell at a good price in a competitive market, they must be chalk white. A few tinted or creamy eggs in a case of white ones will

cause buyers to turn to other shipments that are more nearly uniform. With brown eggs there is more tolerance because of the natural variation in brown shell color, but it is nevertheless true that of two cases that are equal in other respects, the one that is most nearly uniform in shade of brown color will be likely to sell first. All of this simply means that uniformity of shell color gives the seller a price advantage. While there is no relation between shell color and interior quality, there is enough color preference in certain markets to warrant consideration by shippers. Thus New York City has long been known as a white-egg market. In the course of a year it receives many more brown eggs than white eggs, but there is a special demand for large white eggs of strictly top quality and this has meant worth-while premiums to many producers. Boston, on the other hand, has long been regarded as a brown-egg market.

Eggs with rough, thin, or uneven shells are always discriminated against, and should not be shipped to central markets. They should either be used at home or disposed of locally to customers who will appreciate the opportunity to get eggs of high interior quality at less than the regular market price. If the quantity of such eggs warrants, they may be broken out and sold as liquid eggs.

Stained or dirty eggs are unattractive in appearance and must always be sold at a discount. Furthermore, dirty eggs will spoil more quickly than clean eggs, and careless washing makes matters worse because it increases the chance of spoilage. For these reasons it becomes important to do everything possible to prevent the production of dirty eggs.

Studies at the Missouri Station have shown that the percentage of dirty eggs can be very materially reduced by following suitable management practices. When eggs were gathered only once daily, 31 per cent were either dirty or slightly dirty, but when gathered four times daily the percentage dropped to 15. During a six-months period 12.5 per cent of eggs laid in trapnests were soiled, while 29.4 per cent of those laid in open nests were dirty. In the Missouri tests White Leghorns gave more than twice as many dirty eggs on a percentage basis, as did all other breeds combined. Many more dirty eggs were found among those laid before nine o'clock than among those laid later in the day. Perhaps the most significant finding in these tests was that more than 99 per cent of all eggs were clean at the moment of laying and before they came in contact with the nest.

Uniformity helps to sell any product, and eggs are no exception to the rule. A case of eggs weighing 23 ounces to the dozen, if all eggs in it are alike, will be much easier to sell than a heavier case in which there is wide variation in size, shape and color. It nearly always pays to sort eggs before sale or shipment in order to secure reasonable uniformity within each package.

Candling Quality.—External appearance is not an accurate indication of what is to be found inside the shell, and it is therefore customary to make use of the practice known as candling in order to measure interior quality. Accurate candling can best be done in a darkened room with some arrangement for passing the light from a lamp or an electric light bulb through the eggs to the observer. Many of the important differences in interior quality can then be plainly seen. Candling equipment may range from a simple home-made affair costing but a few cents, to an elaborate mechanical device, with which is combined an automatic grader (according to egg weight), costing several hundred dollars. Regardless of the type of equipment, each egg must be individually examined.

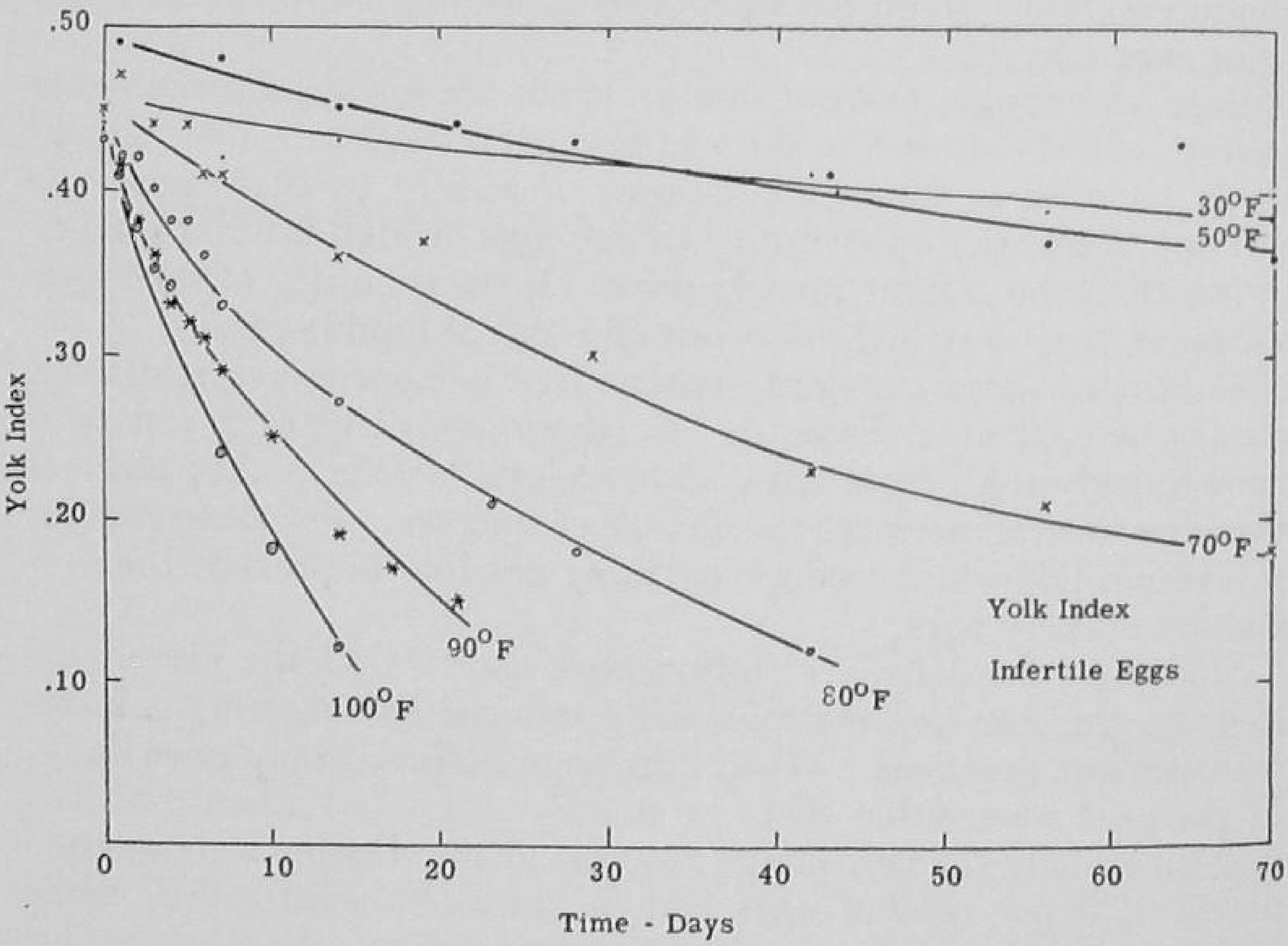


FIG. 159.—Showing the effect of temperature on change in egg quality as measured by the yolk index. (*Courtesy of Missouri Agricultural Experiment Station.*)

The characters used in measuring quality on the basis of candling appearance are shell, air cell, yolk, white and germ. Eggs that have thin, porous or cracked shells are easily detected. None but sound shells should be passed when candling eggs for shipment.

The air space or air cell is usually at the large end of the egg, and can be plainly seen when the egg is candled. It develops between the two membranes that line the shell, and increases in size according to the amount of moisture evaporated from the egg. It should be fixed in position with no tendency to bubble or move about. A bubbly air cell is an indication of staleness and a weak

shell membrane, or of rough handling, while an air cell that moves freely to any part of the egg is the result of a broken inner membrane.

When a strictly fresh egg is candled, the yolk cannot be seen except as a faint shadow. It should remain close to the center of the egg. In an egg of lower quality the yolk moves more freely and casts a darker shadow because it floats nearer to the shell. Much of this difference in appearance is really due to changes in the white, or albumen, rather than to changes in the yolk. In an egg of top quality the white is firm and clear, and so thick or viscous that the yolk does not move freely in it. Under usual holding conditions the egg-white gradually becomes thin, weak and watery in appearance so that the yolk is permitted to move about as the egg is turned. As a result of this condition, the yolk floats close to the shell where it casts a dark shadow and is therefore more plainly seen in candling.

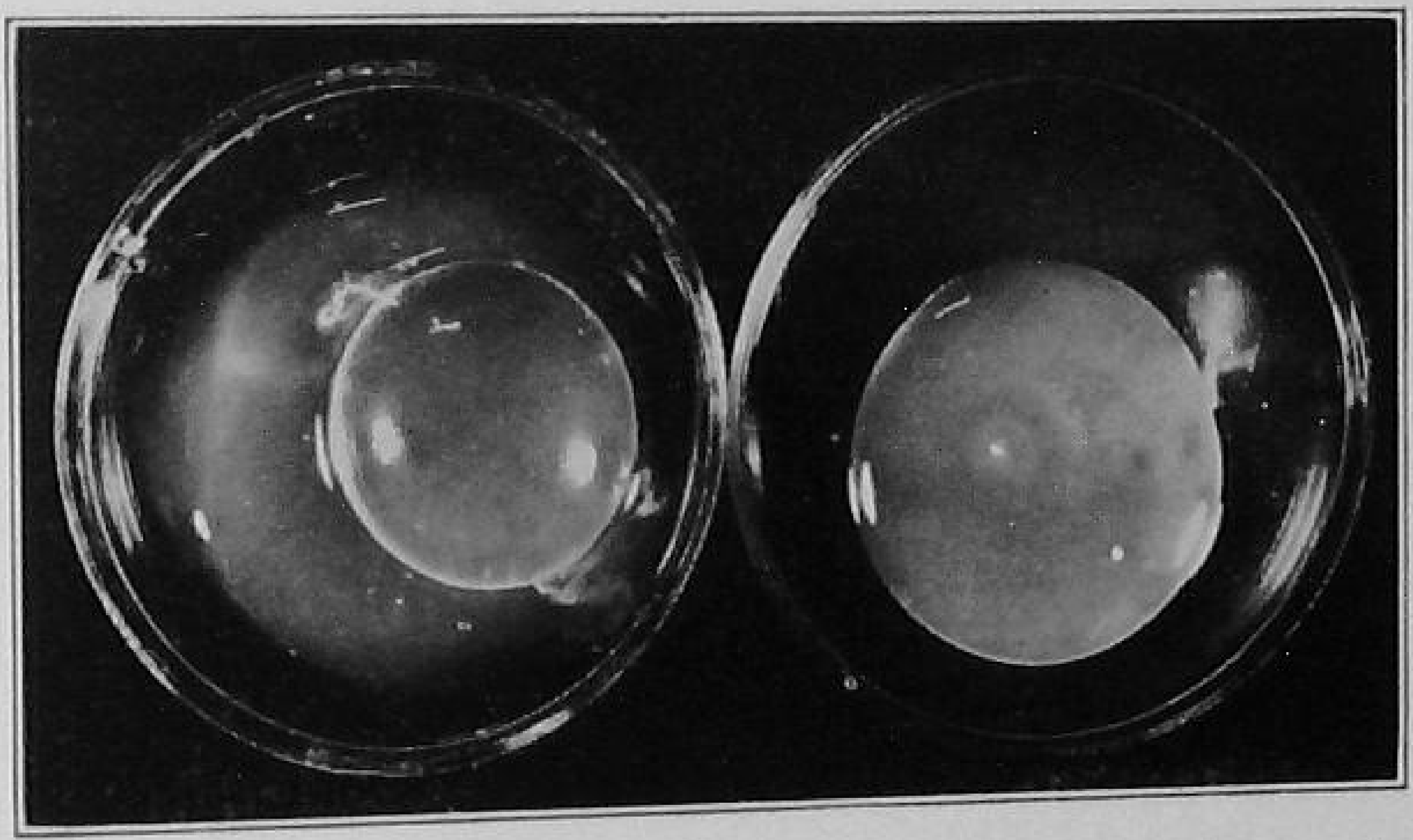


Fig. 160.—Heat is the principal cause of loss in egg quality. A firm yolk and a dense white (left) are quickly changed by heat. The egg shown at the right had been incubated for three days.

High-grade eggs must not show any visible germ development. The greater the germ development the lower the quality. When it has reached the stage at which blood begins to show, the egg is considered unfit for food. This stage will be reached within forty-eight hours when fertile eggs are held at temperatures of 100° to 103° F. The best method of avoiding loss from this cause is to produce no fertile eggs except during the hatching season.

Although most eggs are of excellent interior quality when first laid, there are some faults that occasionally appear in eggs from flocks that are receiving the best of care in every way. Blood clots, bloody eggs, meat spots and body checks may be mentioned as examples. A blood clot is due to the rupture of a small blood-

vessel while the yolk is being formed. The result is that a small clot of blood is enclosed within the egg, usually on the surface of the yolk. Less frequently the clot may be so large as to color most of the white and give it a pink appearance before the candle. It is then referred to as a bloody egg and is unfit for food. Small blood clots can easily be removed after the egg is opened, so that the egg may be used, but such eggs should not be marketed.

Meat spots, as the name suggests, have commonly been described as small bits of tissue from the ovary or oviduct which have become enclosed within the shell during the process of egg formation. Microscopic examination of normal "meat spots" has shown that most of them originate as blood clots, and that their original appearance is altered by degenerative changes in the red blood cells. Small meat spots do not affect the food value of eggs, but large ones are always objectionable. Either sort should be kept out when selling eggs to high-class trade.

Blood and meat spots present a serious problem for the industry, as shown by examination of samples from twenty different flocks in seven midwestern states made by the Illinois Station in May, 1944. Of 3600 eggs from ten Leghorn flocks, 12.5 per cent contained blood spots and 12.8 contained meat spots. Among 3600 eggs from ten commercial flocks of Plymouth Rocks, New Hampshires, and Rhode Island Reds, 36.7 per cent contained blood spots, and an additional 6.1 per cent contained meat spots. Complete methods of prevention and control still have to be worked out, though it is known that both hereditary and nutritional influences are involved.

TABLE 35.—SUMMARY OF UNITED STATES STANDARDS FOR QUALITY OF INDIVIDUAL SHELL EGGS*

Quality factor	U. S. AA quality	U. S. A quality	U. S. B quality	U. S. C quality
Shell	Clean, unbroken, practically normal	Clean, unbroken, practically normal	Clean, unbroken, may be slightly abnormal	Clean, unbroken, may be abnormal
Air cell	$\frac{1}{8}$ inch or less in depth, practically regular	$\frac{2}{8}$ inch or less in depth, practically regular	$\frac{3}{8}$ inch or less in depth, may show movement not over $\frac{3}{8}$ inch; if not over $\frac{3}{8}$ inch, may be free	May be over $\frac{3}{8}$ inch in depth, may be free or bubbly
White	Clear, firm	Clear, may be reasonably firm	Clear, may be slightly weak	Clear, may be weak and watery; small blood clots or spots may be present
Yolk	Well centered, outline slightly defined, free from defects	May be fairly well centered, outline may be fairly well defined, practically free from defects	May be off center, outline may be well defined, may be slightly enlarged and flattened, definite but not serious defects	May be off center, outline may be plainly visible, may be enlarged and flattened, may show clearly visible germ development but no blood, may show other serious defects

* Effective December 1, 1946

A "body check" is an egg in which the shell appears to have been cracked while in the uterus or shell gland, presumably before all of the shell material was formed. The break is then sealed by the deposition of additional shell material, so that after being laid it appears normal when given but casual inspection. The weak shell is easily detected by candling. Such eggs should not be shipped because of the greater likelihood of breakage.

The official United States standards for quality of individual eggs with clean unbroken shells are summarized in Table 35. These have been in effect since December 1, 1946. Official standards have also been set up for quality of individual eggs with dirty unbroken shells, and for eggs with checked or cracked shells, as follows:

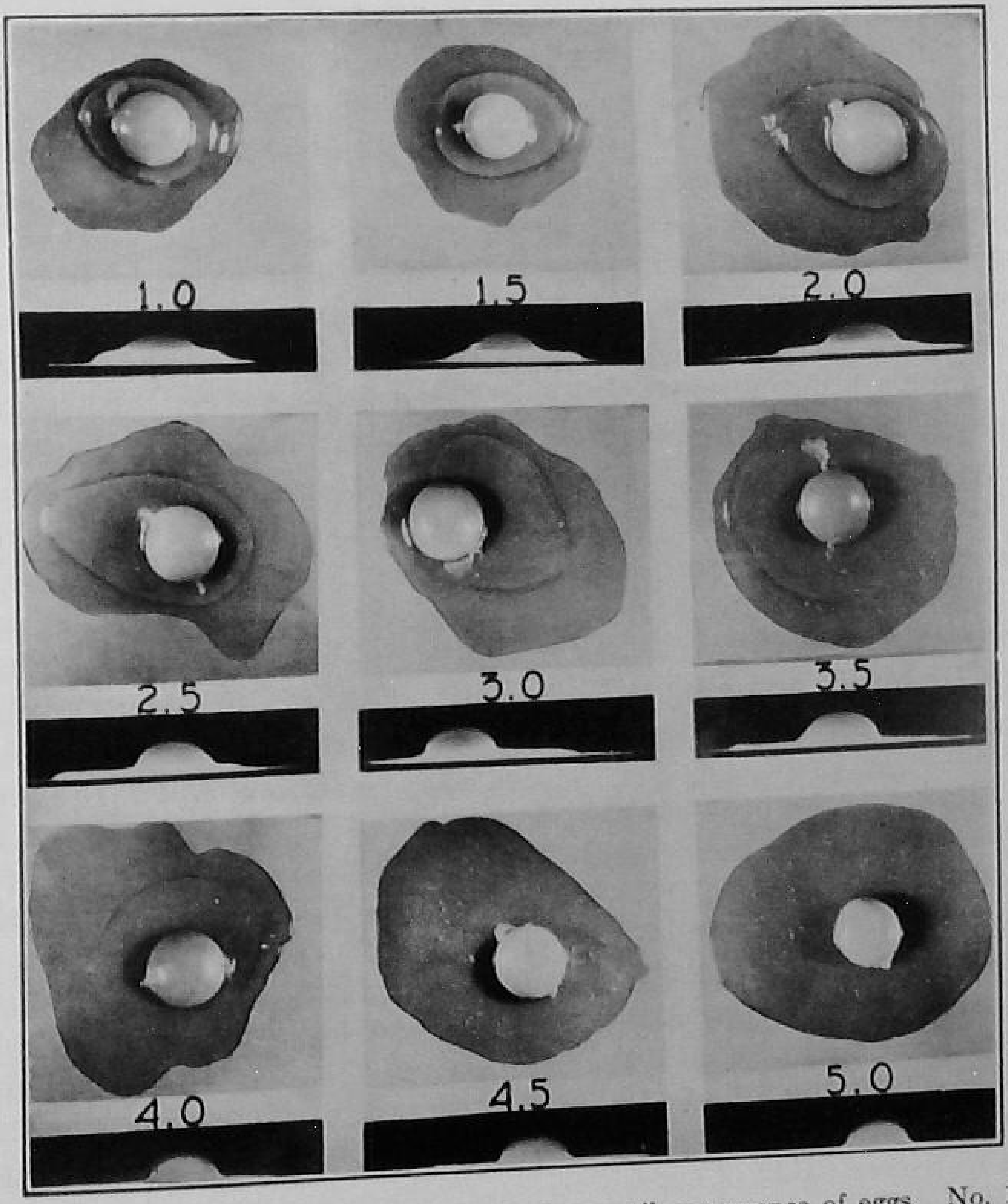


FIG. 161.—Successive stages in the "broken out" appearance of eggs. No. 1 is approximately equivalent to U. S. AA quality, No. 2 to U. S. A quality, No. 3 to U. S. B quality, and No. 4 to U. S. C quality. *(Courtesy of Institute of American Poultry Industries.)*

U. S. Standards for Quality of Individual Eggs with Dirty Unbroken Shells:

Stained.—An individual egg that has no adhering dirt and no more than a combined total of $\frac{1}{8}$ of the shell surface stained or soiled.

Dirty.—An individual egg that has adhering dirt or more than a combined total of $\frac{1}{8}$ of the shell surface stained or soiled.

U. S. Standards for Quality of Individual Eggs with Checked or Cracked Shells:

Check.—An individual egg that has a broken shell or crack in the shell but with no leakage of the contents.

Leaker.—An individual egg that has a broken shell or crack in the shell and shell membranes with the contents exuding or free to exude through the shell.

Detailed definitions of terms used in describing eggs which conform to the various standards and grades have been prepared in mimeographed form, and may be obtained from the U. S. Department of Agriculture, Washington 25, D. C.

Quality of Opened Eggs.—There are some characteristics of eggs that cannot be observed until the eggs are opened. These include odor, flavor and color of yolk. Since eggs will very quickly absorb odors of various sorts, it is important that they be handled at all times in such a way as to prevent contact with any materials that might cause an undesirable odor or flavor. If eggs are laid in nests which have been recently treated with creosote, they may be tainted in flavor. Fumigation of fowls or poultry houses with such substances as nitrobenzene may also result in the production of strong-flavored eggs. Hens on range have been known to eat large numbers of army worms and, in consequence, lay eggs which are decidedly off in color and flavor. Undesirable flavors and odors are supposed to result from the feeding of such materials as onions, rape and garlic, and it has also been suggested that the feeding of grain which has recently been treated with formalin will likewise cause an undesirable odor in the eggs laid.

The color of yolk is almost entirely a matter of feeding, though it appears to be influenced somewhat by the rate of laying of an individual hen. The liberal use of xanthophyll-bearing feeds, such as fresh or dried green roughage and yellow corn, will result in the production of deep yellow yolks, whereas the feeding of rations in which these materials are restricted will cause the production of pale yolks. This has already been discussed in some detail in connection with feeding. Except as certain feeds supply both vitamin A and yellow pigment, and hence affect the product in both particulars, there is probably no correlation between yolk color and the nutritive value of eggs.

The differences, seen in candling, between an egg with a firm white and a well-centered, dimly-visible yolk, and an egg with a watery white and prominent yolk, are even more pronounced when

the eggs are opened. The yolk of the first egg will appear well rounded, while that of the second will be flattened and spread out. The white of the first egg will stand up well, suggesting the original shape of the unopened egg, while that of the second will be watery in appearance and quite without shape. Attempts to influence this condition by feeding have, as a rule, been unsuccessful. Although it has been shown that holding conditions affect the rate of change in viscosity of the white, it appears that the individual hen is a more important factor. The most promising means of bringing about improvement in this respect are selection and breeding, using hens that possess the desired characteristics, and sons of such hens.

Other Measures of Quality.—Various attempts have been made to devise more exact measures of egg quality in order that careful scientific studies can be undertaken of the factors that influence quality. The yolk index is a measure of the standing-up quality of the yolk. It is obtained by dividing the height of the yolk by its average diameter. The measurements are made after the egg is broken out into a small plate. Average values for fresh eggs usually fall between 0.42 and 0.40. As the yolk becomes flattened the yolk index is lowered. When the value of the index is 0.25 or lower, the yolk is so weak that it is extremely difficult to handle it for measurement without breaking.

Deterioration in the eggs of individual hens has been measured by recording the percentage of thick and thin egg-white. As the yolk increased in weight due to absorption of water from the white, the percentage of thick white decreased. The rate of change in percentage of thick white, under uniform holding conditions, was a characteristic of individual hens, and there was considerable variation among hens in this respect. The concentration of water in thick white remained exactly equal to that in the associated thin white, regardless of losses to the yolk and to the atmosphere.

Albumen score has been used by workers at the Cornell Station, and is in many respects the simplest of all measures to apply. The scale of scores is illustrated in Figure 161.

Workers at the California Station have described a method for the study of egg-shell porosity, and have suggested a set of standards of comparison to be used with the method. The standards are shown in Figure 162. These workers found that the initial porosity in fresh eggs was normally low, that it was rather uniformly distributed over the egg surface, and that it increased with holding time, more rapidly at higher temperatures. In eggs held for twenty-five days at room temperature the porosity increased from about Score 4 or 5 to Score 8 or 9.

Producer Control of Egg Quality.—It has already been stated that eggs are highly perishable. A fact of equal significance is that no process has yet been found for improving an egg of poor quality.

It is rather obvious, then, that in any successful marketing plan emphasis must be placed on those practices that will insure the production of high-quality eggs, and on handling methods that will preserve their original quality as long as possible. The importance of selection and breeding for desired egg characteristics, and of feeding and management looking toward high-quality eggs, have been discussed in previous chapters. Care and handling of eggs before they leave the farm is also important.

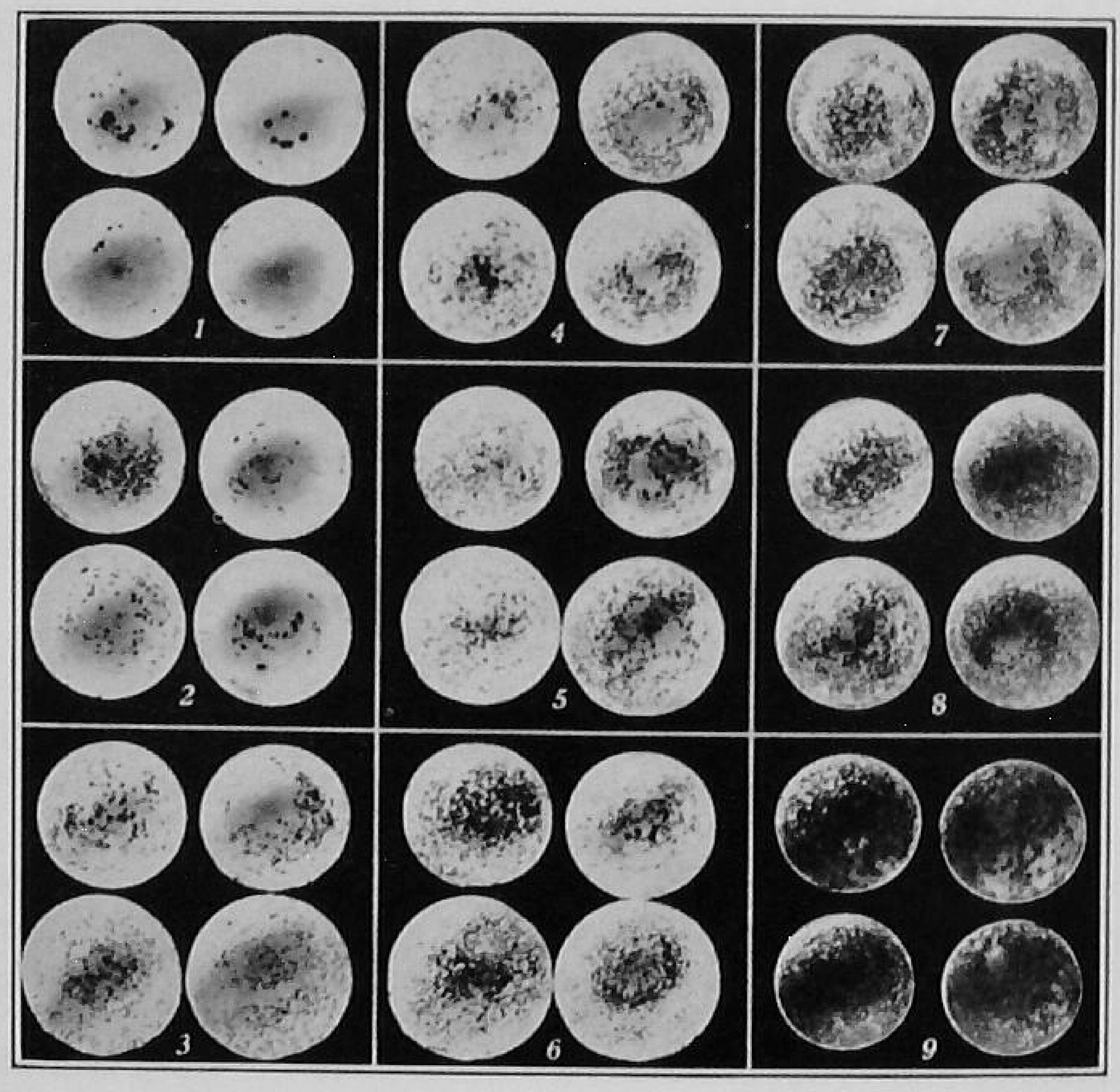
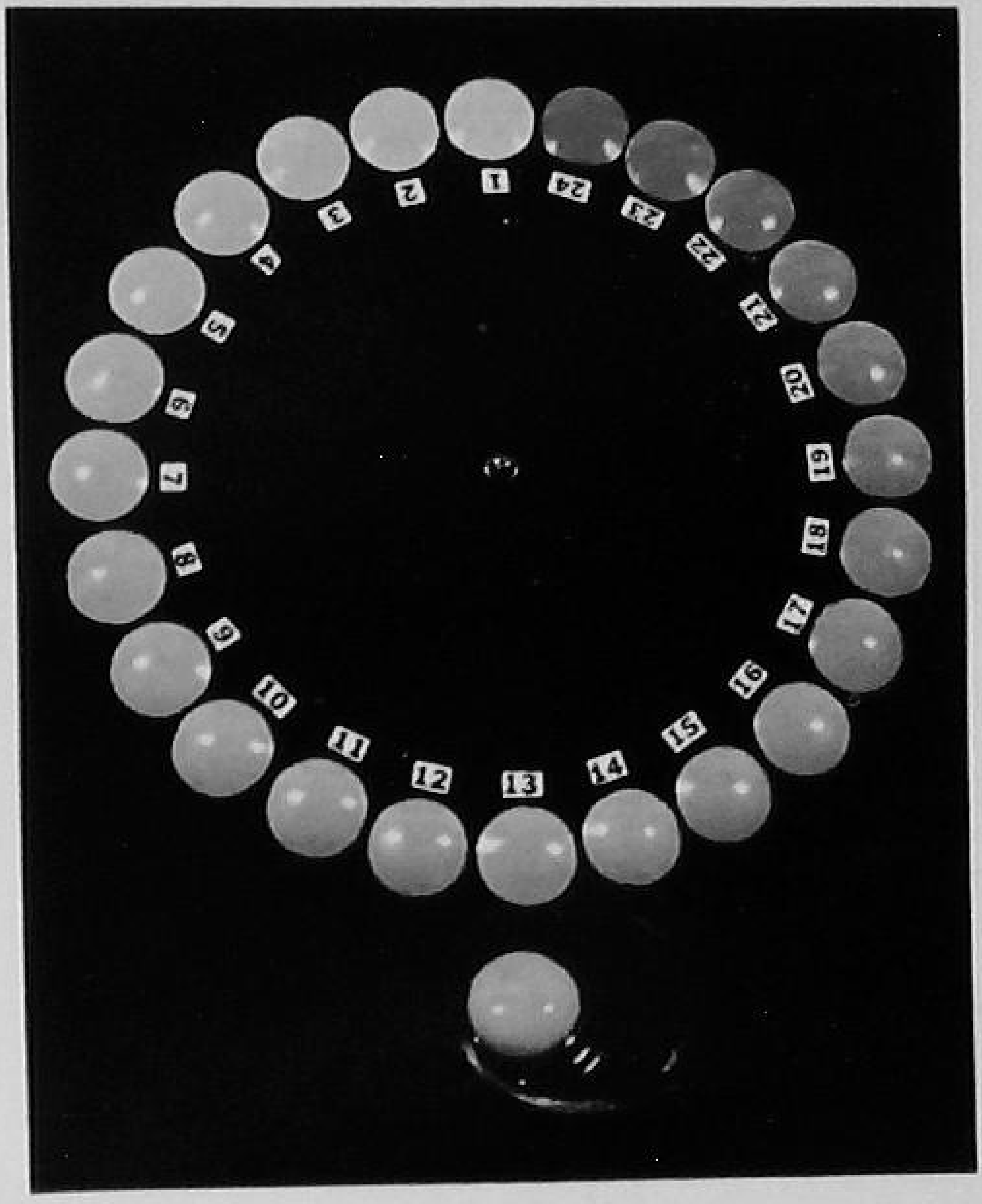


FIG. 162.—Variation in shell porosity. The numbers *1* to *9* represent increasing shell porosity as shown by the increasing number of small spots on the interior of the shells. Both halves of each shell are shown, with air-space ends to the left. (*Courtesy of California Agricultural Experiment Station.*)

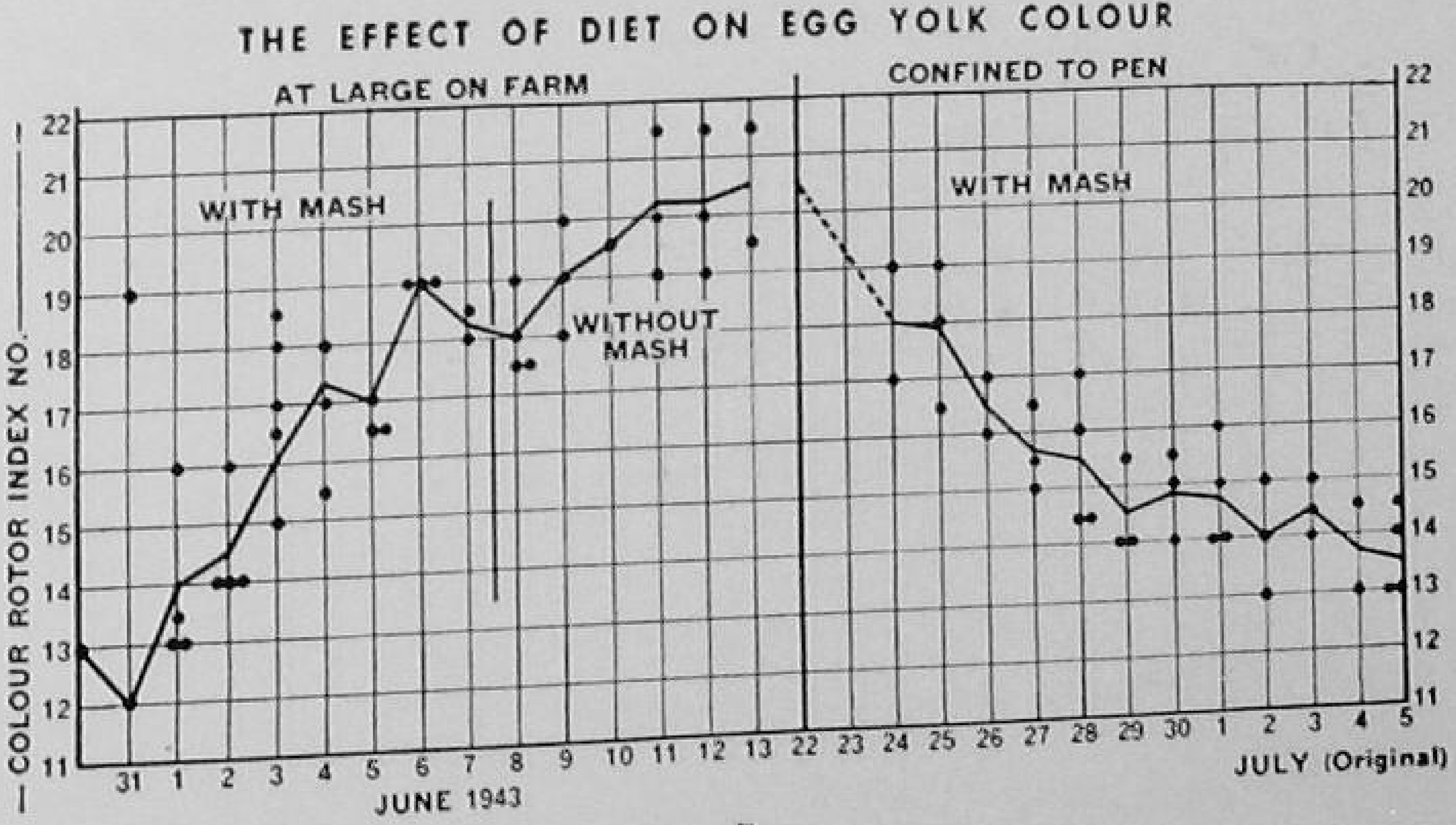
Care and Handling of Eggs on the Farm.—Except for those quality factors that are definitely controlled by inheritance and by feeding, the production of high-quality eggs is a matter of careful attention to a few details that do not require any elaborate buildings or equipment.

The first rule to remember is that fertile eggs should not be produced except for hatching purposes. As mentioned in connection with incubation, when a fertile egg is held at a temperature above 80° F., the germ begins to develop. In the early stages the develop-

PLATE IV



A



B

A, Heiman-Carver Yolk Color Rotor, a device for measuring yolk color by direct comparison.

B, Effect of feed on yolk color. Pullets which had been laying eggs with pale yolks (Rotor Nos. 12 to 14) when confined indoors, quickly produced darker yolks (Rotor Nos. 19 to 22) when turned out on range, especially when deprived of mash. When the pullets were returned to the original quarters and method of feeding, yolk color quickly became pale, as before. *(Courtesy of Ontario Department of Agriculture.)*

ment is referred to by market men as a "hatch spot," but in a very short time blood appears and thereafter the egg must be classed as inedible. A lower temperature at this stage will kill the tiny embryo and then decomposition will begin. This is the explanation for so many rotten eggs appearing on the market every year. An infertile egg seldom rots, and if none but infertile eggs were ever sent to market the poultry industry would be saved millions of dollars each year.

As has already been mentioned, dirty eggs must always be sold at a discount in a competitive market, and since washing usually makes matters worse from the standpoint of keeping quality, the aim should be to prevent dirty eggs insofar as possible. Some practices that will help in reducing the number of dirty eggs to a minimum are: (1) To provide abundant floor space (not less than 4 square feet per hen); (2) to provide plenty of nests (not fewer than 20 nests for 100 hens); (3) to change litter and nesting material frequently so they will not become damp and dirty; (4) to provide droppings boards under the roosts and to have them screened so that the hens cannot walk in the droppings; and (5) to confine the layers until about 2 P.M. or later on days when the yards are muddy.

Tests at the Missouri Station have shown that dirty eggs can be cleaned effectively by using solutions of sodium hydroxide (lye water). Eggs cleaned in this manner kept equally as well in cold storage as clean eggs which were not washed. To obtain satisfactory results, it is essential that a sufficiently strong solution be used, and that not too many eggs be cleaned before making up a new solution. As many as 15 dozen dirty eggs could be cleaned with three quarts of water containing 0.35 per cent of sodium hydroxide before the solution became ineffective. Rubber gloves must be used when washing eggs in such caustic solutions.

Various detergents can be used for washing eggs that are going to nearby markets for immediate consumption. Mechanical washers are often used for dirty eggs which must go through breaking plants. In all such cases the water used should be warmer than the eggs, even up to 140° F., in order to avoid shrinkage of the egg contents which may draw bacteria and other fine material through the pores of the shell.

There are also available abrasive mechanical cleaners which do a very satisfactory job on white eggs. They may remove some of the color from brown eggs.

Even the best of eggs will reach the market in poor condition unless they are properly handled between the time they are laid and the time they leave the farm. A few simple practices, if rigidly carried out, will reduce this loss to a minimum. Eggs should be gathered from the nests at least twice a day at all seasons of the year, and in very hot weather they should be collected three or more times every day. This practice helps to prevent damage

The handling of shell eggs prior to drying is no different from the handling of eggs which are to be frozen. The liquid egg material is put through a clarifier to remove any bits of shell, and is then screened to remove the chalazæ and vitelline membranes. In most plants the product is then flash pasteurized for 30 seconds at a temperature of about 140° F. This preheating is also essential if a low-moisture powder is to be produced without any scorching.

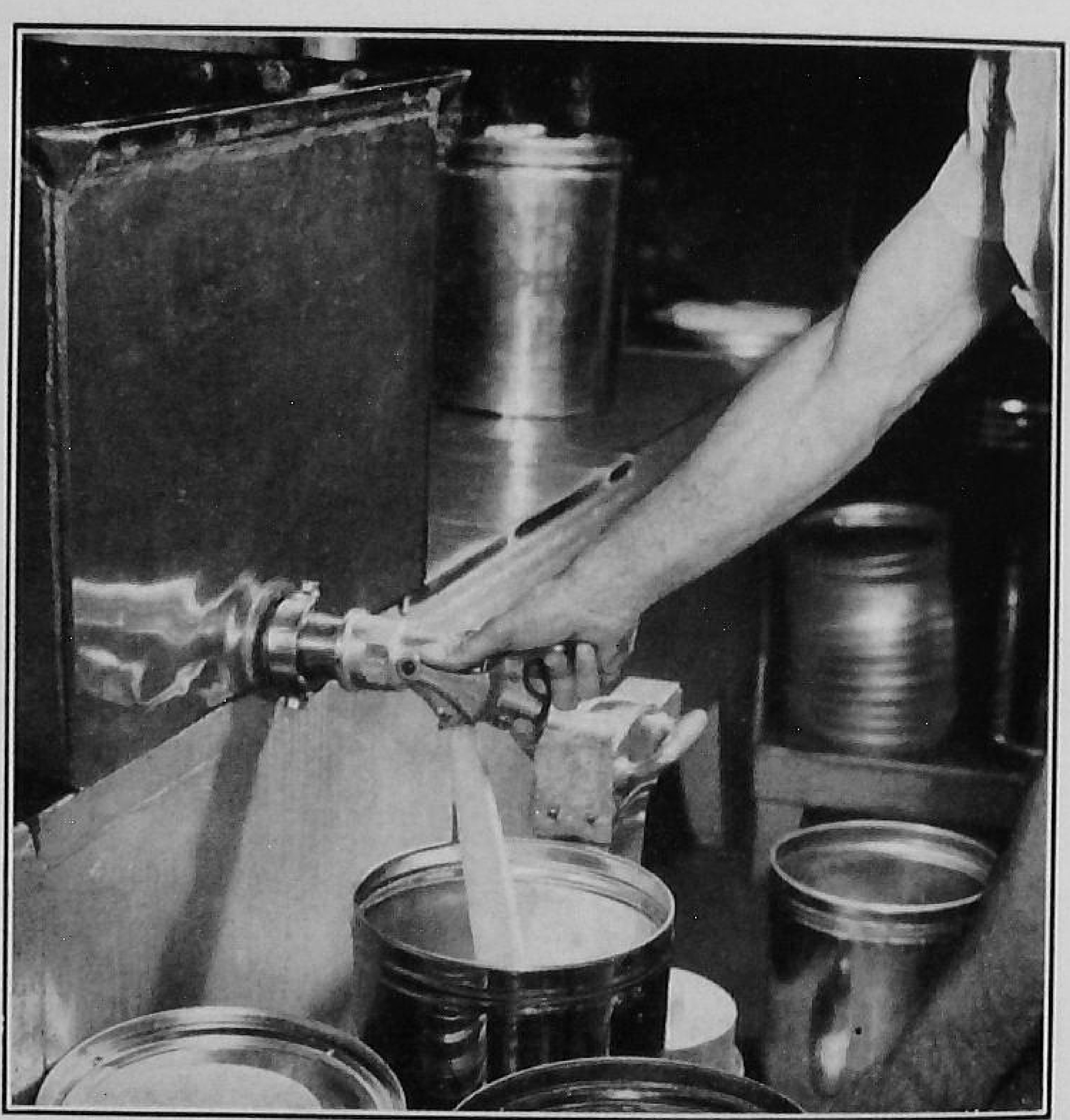


FIG. 167.—Broken whole eggs are thoroughly mixed and run into tin cans preparatory to freezing. (*U. S. Department of Agriculture. Photograph by Forsythe.*)

The liquid egg is then pumped under pressure of 2500 to 5000 pounds per square inch to nozzles through which it is released into a large chamber where it comes immediately into contact with a stream of air which has been heated to temperatures of 250° to 350° F. This causes instantaneous evaporation of most of the moisture from the egg material, which falls to the floor as a fine powder while the moist air passes on out of the drying chamber at a temperature of 150° to 160° F.

Modern driers produce a powder in which the moisture content does not exceed 2 per cent. The temperature of the powder as it leaves the drier may be 150° F. or higher, and this must be reduced quickly to less than 85° F. if the product is to have good keeping qualities. Since the powder is extremely hygroscopic, the temperature must be reduced by contact cooling rather than by exposure

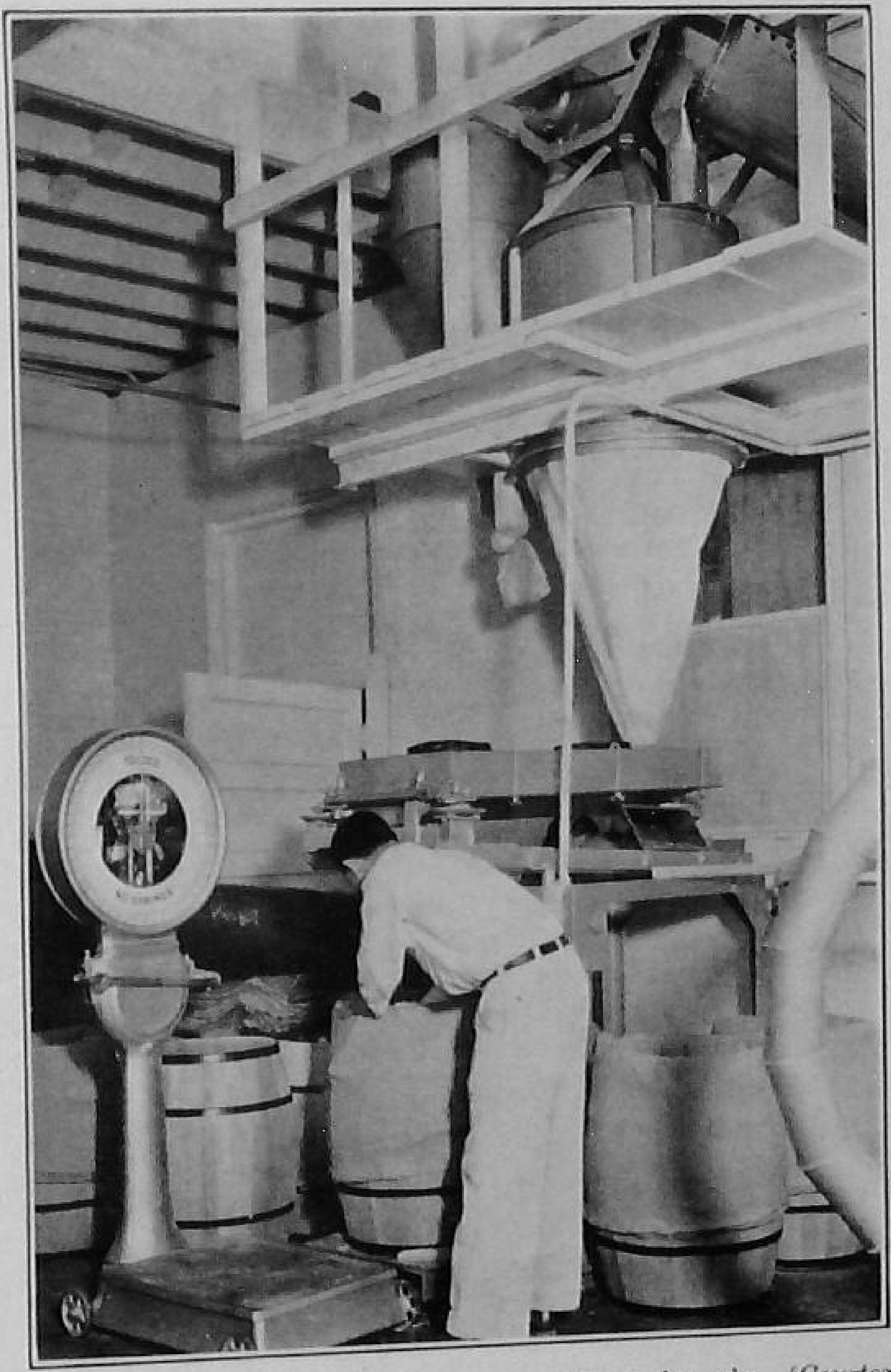


FIG. 168.—Dried egg powder is packed commercially in barrels. (*Courtesy of U. S. Egg and Poultry Magazine.*)

to cold air. The powdered eggs are then packed immediately in sealed containers. Many of them are packed in carbon dioxide to remove the oxygen and lower the pH value in order to improve the keeping quality of the product.

Methods of Egg Marketing.—In most communities there will be more than one method of marketing available to the producer of

Hen or Stewing Chicken or Fowl.—A hen or stewing chicken or fowl is a mature female chicken (usually more than 10 months old) with meat less tender than that of a roaster, and non-flexible breastbone.

Cock or Old Rooster.—A cock or old rooster is a mature male chicken with coarse skin, toughened and darkened meat, and hardened breastbone.

Standards of quality for live poultry on an individual bird basis are summarized in Table 38, and those for individual carcasses of dressed and ready-to-cook chickens in Table 39. Detailed specifications for the various grades are based on these standards of quality, and copies may be obtained from the U. S. Department of Agriculture, Washington 25, D. C.

TABLE 39.—SUMMARY OF SPECIFICATIONS FOR STANDARDS OF QUALITY FOR INDIVIDUAL CARCASSES OF DRESSED AND READY-TO-COOK CHICKENS

(Minimum Requirements and Maximum Defects Permitted)

Factor	A quality		B quality		C quality	
Conformation:	Normal		Practically normal		Abnormal	
Breastbone	Slight curve, ⅛" dent		Dented, curved, slightly crooked		Seriously crooked	If fairly well fleshed
Back	Normal (except slight curve)		Moderately crooked		Seriously crooked	If fairly well fleshed
Legs and Wings	Normal		Moderately misshapen		Misshapen	
Fleshing:	Well fleshed, moderately long and broad breast		Fairly well fleshed on breast and legs		Poorly fleshed	
Breastbone	Not prominent		Not prominent		May be prominent	
Fat covering	Well covered—some fat under skin over entire carcass Broilers or fryers only moderate covering		Sufficient fat on breast and legs to prevent a distinct appearance of flesh through skin		Lacking in fat covering over all parts of carcass	
	Breast and legs	Elsewhere	Breast and legs	Elsewhere	Breast and legs	Elsewhere
Pinfeathers:						
Dressed						
Pins and hair	Pract. free	Pract. free	Relatively few	Sl. scattering	Numerous	Numerous
Ready-to-cook						
Non protruding pins	Pract. free	Pract. free	Few scattered	Few scattered	Scattering	Scattering
Protruding pins and hair	Free	Free	Free	Free	Free	Free
Cuts and Tears:[1]	Free	1½"	1½"	3"	No limit	
Disjointed bones	1		2		No limit	
Broken bones	None (except one non-protruding if broiler or fryer)		1 Non-protruding		No limit	
Discolorations:[2]						
Flesh bruises	0"	½"	½"	1½"	No limit[3]	
Skin bruises	½"	¾"	¾"	1½"	No limit[3]	
All discolorations	1"	1½"	1½"	3"	No limit[3]	
Freezer burn	Few small (⅛" diameter) pockmarks		Moderate-dried areas not in excess of ½" in diameter		Numerous pockmarks and large dried areas	

The quality designations specified herein are not applicable to birds possessing any of the following conditions: dirty or bloody head or carcass, dirty feet or vent, fan feathers or neck feathers or garter feathers, or feed in the crop.

[1] Total aggregate length of all cuts and tears including incision for removal of the crop or its contents.

[2] Maximum diameter of aggregate areas of all flesh bruises, skin bruises and discolorations.

[3] No limit on size and number of areas of discoloration and flesh bruises if such areas do not render part of carcass unfit for food.

Standards effective January 1, 1950.

Marketing Dressed Poultry.—Dressed poultry is marketed either as fresh-killed or as frozen poultry. Since about one-half of the poultry goes to market in the four months of October, November, December and January, some of it must be held over in cold storage in order to supply the needs of the trade during the season of short supply. Such poultry is frozen hard and can be held for several months in excellent condition. Fresh-killed poultry is simply dressed poultry that has not been frozen.

FIG. 179.—This portable picker contains two rotating drums. With it one operator can pick 150 birds an hour. (*Courtesy of Barker Poultry Equipment Company.*)

Poultry that is dressed for local consumption is commonly scalded in hot water in order that the feathers may be easily removed. After it has cooled, it is usually less attractive in appearance than is dry-picked poultry. When the latter method is followed, however, it is necessary that each bird be debrained in a special manner so that the feathers will be loosened for easy picking.

the kidney area within twenty-four hours, and spread gradually to other parts of the carcass, finally reaching the wing joint in about four days. Prompt chilling is therefore very important, and for best results poultry should be frozen quickly at low temperatures very soon after killing.

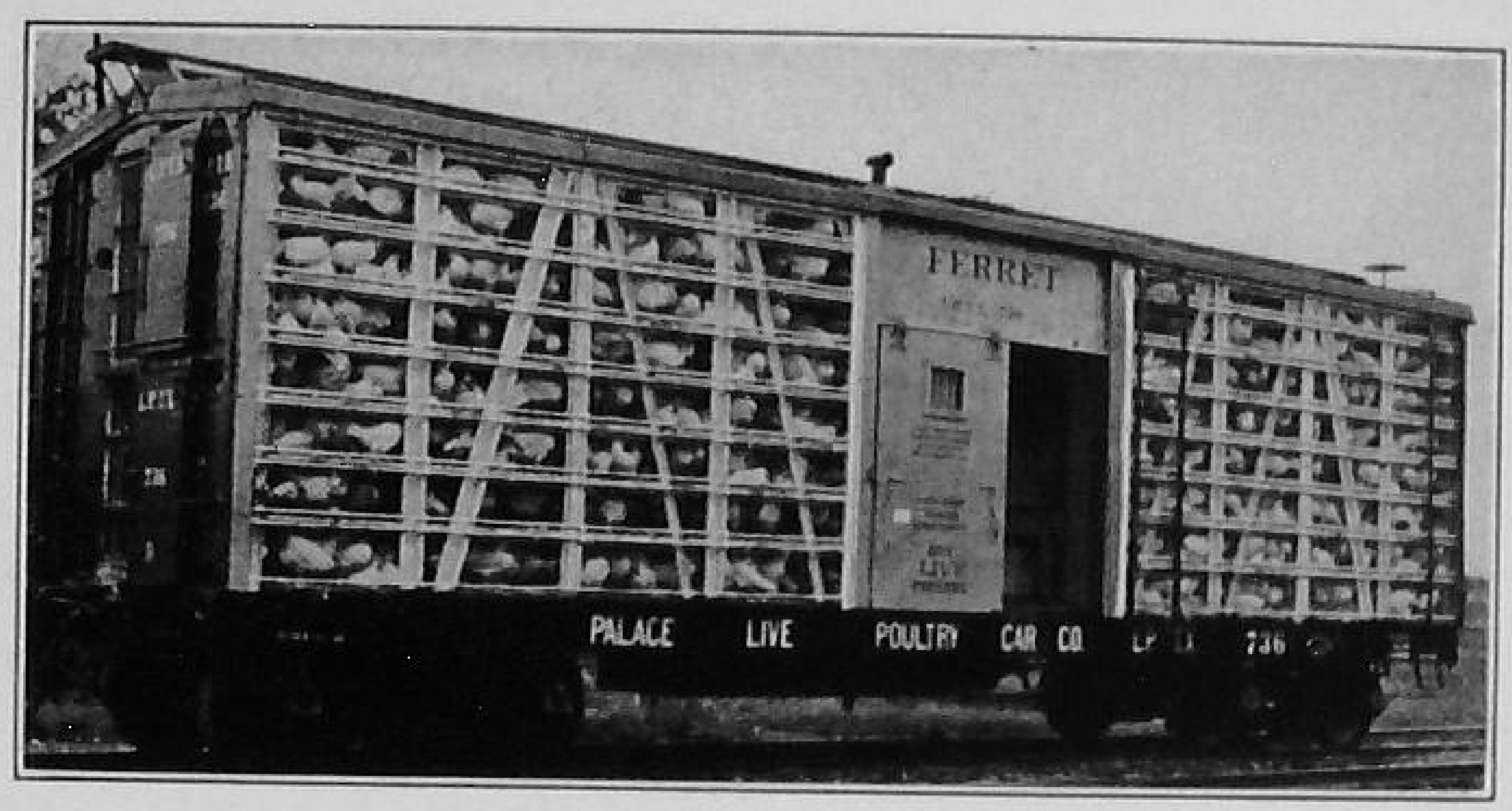


FIG. 191.—Live poultry has long been shipped to the central markets in special cars such as the one shown here. An aisle down the center of the car permits the carman to feed and water the birds while en route to market. (*Courtesy of Institute of American Poultry Industries.*)

Commercially dressed, slack-scalded poultry is commonly packed dry in boxes, 12 birds to a box, and is shipped to the central markets in refrigerator cars. It is referred to as dry-packed poultry in order to distinguish it from ice-packed poultry which is usually packed in barrels with a layer of crushed ice between each two layers of poultry. This latter method is used for shipment to nearby markets. With long-distance shipment, dry-packed poultry usually reaches the market in better condition than ice-packed stock, and for this reason is likely to bring a better price.

TABLE 42.—DISTRIBUTION OF BROILERS MARKETED FROM THE DELMARVA AREA, BY WEIGHT CLASSES, FOR THE YEAR BEGINNING OCTOBER, 1949

Average New York dressed weight	*Millions of pounds marketed*	*Per cent of total*
2 pounds and under	41.6	12.0
2½ pounds	114.5	32.9
3 "	86.2	24.8
3½ "	59.1	17.0
4 "	26.2	7.5
4½ "	12.9	3.7
5 pounds and over	5.6	1.6
Off grade	2.0	0.6
Total	348.1	100.1

Much dressed poultry is still shipped to market undrawn. The only preparation is the removal of blood and feathers. More and more poultry is being eviscerated and sold full-drawn, ready for the pan or oven. Some of it is quick frozen within a very short time after killing. In the preparation of such poultry the entrails are removed, and the head, feet and shanks cut off. The gizzard is cleaned and, together with the heart, liver and neck, is wrapped in parchment paper and placed inside the bird. The drawn carcasses are then individually wrapped in cellophane and quickly frozen at a temperature of −20° F. or lower. For best results they must be held and transported in a hard frozen condition until they are ready for delivery to the final consumer.

Consumers are occasionally disturbed by the appearance of dark coloration sometimes seen in the bones of poultry which has been frozen. Freezing and thawing of the carcass act to hemolyze the red cells of the bone marrow, and to make it possible for the hemoglobin which is thus released to penetrate the outer surface of the bones. This is what causes the discoloration. It occurs more readily in young chickens as fryers than in older poultry.

Millions of pounds of broilers and fryers are prepared for market by being cut up and packaged, ready to cook. This has become possible with the widespread installation of refrigerated counters in retail stores and markets.

There are also many retail markets in which it is possible to buy half a chicken, one quarter of a turkey, or parts of a chicken such as breasts, legs, wings or giblets.

Commercial canning of poultry is on the increase. More than 150 million pounds, dressed weight basis, were canned in 1950 and preliminary figures indicate an increase of 25 per cent for 1951. Federal inspection of poultry for processing as ready-to-cook meat covered 338 million pounds in 1950 and about 500 million in 1951.

Killing, Dressing and Eviscerating Losses.—Weight losses represented by inedible parts of the chicken are important to both producer and processor, because they are the basis upon which maximum paying prices should be adjusted in relation to the market price of the final product. They are also related to feeding practices just prior to killing.

Killing and dressing losses consist of feathers and blood. The amount of blood lost is close to 4 per cent of the live weight. This means a tenth of a pound for a 2½-pound broiler and up to a fourth of a pound for a large roaster. The weight loss represented by feathers is more variable, but will average about 5 per cent of the live weight. It is higher for females than for males, and lower for short-feathered chickens such as Cornish than for the more heavily feathered breeds.

Records for twenty lots of 300 chickens each in the 1951 Maine Broiler Production Test, when all were killed and dressed at the

same time, showed an average killing loss of 8.8 per cent. The average live weight of these chickens at time of slaughter was 4.94 pounds (cockerels and pullets combined). The lowest shrink for any lot was 6.0 per cent, and the highest 12.4 per cent. For a plant dressing 10,000 head daily, this difference, at 35 cents a pound, represents an extra processing cost of about $1100 a day. The difference between 12.4 per cent and the average of 8.8 per cent, figured at the same price, is over $600 a day for such a plant. It is not surprising that dressing plant operators have definite preferences for certain types of poultry.

Killing and dressing losses are sometimes complicated by the amount of feed remaining in the crops but under ordinary conditions, when soft feed (as opposed to whole grain) is being fed, a fasting period of four hours prior to slaughter is sufficient. This will allow time for the crop to become empty, and for the intestinal contents to be reduced to a satisfactory point. About 60 per cent of the 24-hour fasting loss of intestinal contents occurs in the first three or four hours.

TABLE 43.—EXPECTED YIELD IN POUNDS OF DRESSED WEIGHT, EVISCERATED WEIGHT AND EDIBLE MEAT WEIGHT AS RELATED TO LIVE WEIGHT. (CALCULATED FROM DATA PUBLISHED BY THE U. S. DEPARTMENT OF AGRICULTURE AND OHIO STATE UNIVERSITY.)

Average live weight (pounds)	From 100 pounds live weight: Dressed weight (a)	Dressed weight (b)	Eviscerated (with giblets) (a)	Eviscerated (with giblets) (b)	Edible meat (with giblets) (a)	From 100 pounds dressed weight: Eviscerated (with giblets) (a)	Edible meat (with giblets) (a)
2.0	83.2	87.8	65.6	71.7	55.7	78.9	67.0
2.5	84.4	88.4	67.1	72.0	56.7	79.5	67.2
3.0	85.2	88.9	68.1	72.0	57.4	80.0	67.4
3.5	85.7	89.3	68.8	72.1	57.9	80.3	67.5
4.0	86.2	89.5	69.4	72.2	58.2	80.5	67.5
4.5	86.5	89.8	69.8	72.3	58.5	80.6	67.6
5.0	86.8	89.9*	70.1	72.3*	58.7	80.7	67.6
5.5	87.1	90.0*	70.4	72.4*	58.9	80.8	67.6
6.0	87.2	90.1*	70.6	72.4*	59.0	80.9	67.7

(a) McNally and Spicknall, 1949 (chilled weight basis) battery-raised R. I. Red males slaughtered in groups of 25 at bi-weekly intervals.
(b) Jaap, Renard and Buckingham, 1950 (fresh dressed weight basis) over 1600 males from 44 strains, all slaughtered at 12 weeks of age.
* These values are extrapolations beyond the 4.5-pound maximum live weight attained at 12 weeks of age by chickens used in the Ohio tests.

Eviscerating losses are influenced by the plumpness and degree of finish of the carcasses and, like dressing losses, they tend to be greater with small chickens than with large. Chickens which are grown to market weight on rations high enough in energy to produce a good covering of fat will show a lower eviscerating loss than will chickens which for any reason are somewhat thin or poorly finished.

Not too many reports have been published showing actual yields in terms of eviscerated weights or edible meat. Data from two tests, at Beltsville, Maryland, and Columbus, Ohio, are summarized in Table 43. More information of this sort is needed, especially as related to different degrees of finish.

Marketing Live Poultry.—The live-poultry industry is one of considerable magnitude, with New York City as the principal market outlet. Until recent years, only about 20 per cent of the receipts of live poultry in that market came from nearby points. The balance was largely in the form of car-lot shipments from the western producing sections. Freight shipments into New York increased from about 2000 cars a year in 1900-1905 to 12,000 cars in 1927, the highest year of record. From this high point, freight receipts have continued to decline. Only about 1000 cars were received in 1944.

Truck receipts, on the other hand, have steadily increased. Truck and express receipts made up more than 80 per cent of the total at New York in 1943 and 1944. In 1949, over 99 per cent of the live poultry arrived by truck.

TABLE 44.—HOLIDAYS THAT AFFECT THE DEMAND FOR POULTRY (WITH DATES FOR 1953).

Holiday	*Date, 1953*	*Kinds of poultry particularly desired*
New Year's Day	Jan. 1	Turkeys, geese, fowls, capons
Purim	March 1	Fowls and hen turkeys
Pessach—First Days (Passover)	March 31–April 1	Heavy fowls, fat ducks, geese, turkeys
Easter	April 5	Broilers, roasters
Pessach—Last Days (Last Passover)	April 6–7	Heavy fowls
Shevuoth (Feast of Weeks)	May 20–21	Prime quality of all kinds
Memorial Day	May 30	Broilers
Independence Day	July 4	Broilers, fryers
Rosh Hashanah (Jewish New Year)	Sept. 10–11	Fat fowls, turkeys, ducks, geese
Yom Kippur (Day of Atonement)	Sept. 19	All prime stock
Succoth—First Days (Feast of Tabernacles)	Sept. 24–25	Ducks, geese, fat fowls
Succoth—Last Days* (Feast of Tabernacles)	Oct. 1–2	Prime quality of all kinds
Columbus Day	Oct. 12	Roasters, fowls
Thanksgiving Day	Nov. 27	Turkeys, geese, fowls, capons
Hanukka (Feast of Dedication)	Dec. 2–9	Prime quality of all kinds
Christmas Day	Dec. 25	Turkeys, geese, fowls, capons

* The last, or ninth, day is also called Simchas-Torah (Feast of Law).

It is estimated that about 80 per cent of the live poultry that enters the metropolitan area of New York City is consumed by Jewish people, and the growth of the industry has corresponded

rather closely with the growth of the Jewish population. The live-poultry industry in this market is greatly influenced by Jewish customs and religion, and many of the peculiarities of the industry are traceable to them. For example, the orthodox Jewish church requires that poultry be kosher killed, that is, a deputy of the Jewish rabbi (shochet) must slaughter the bird.

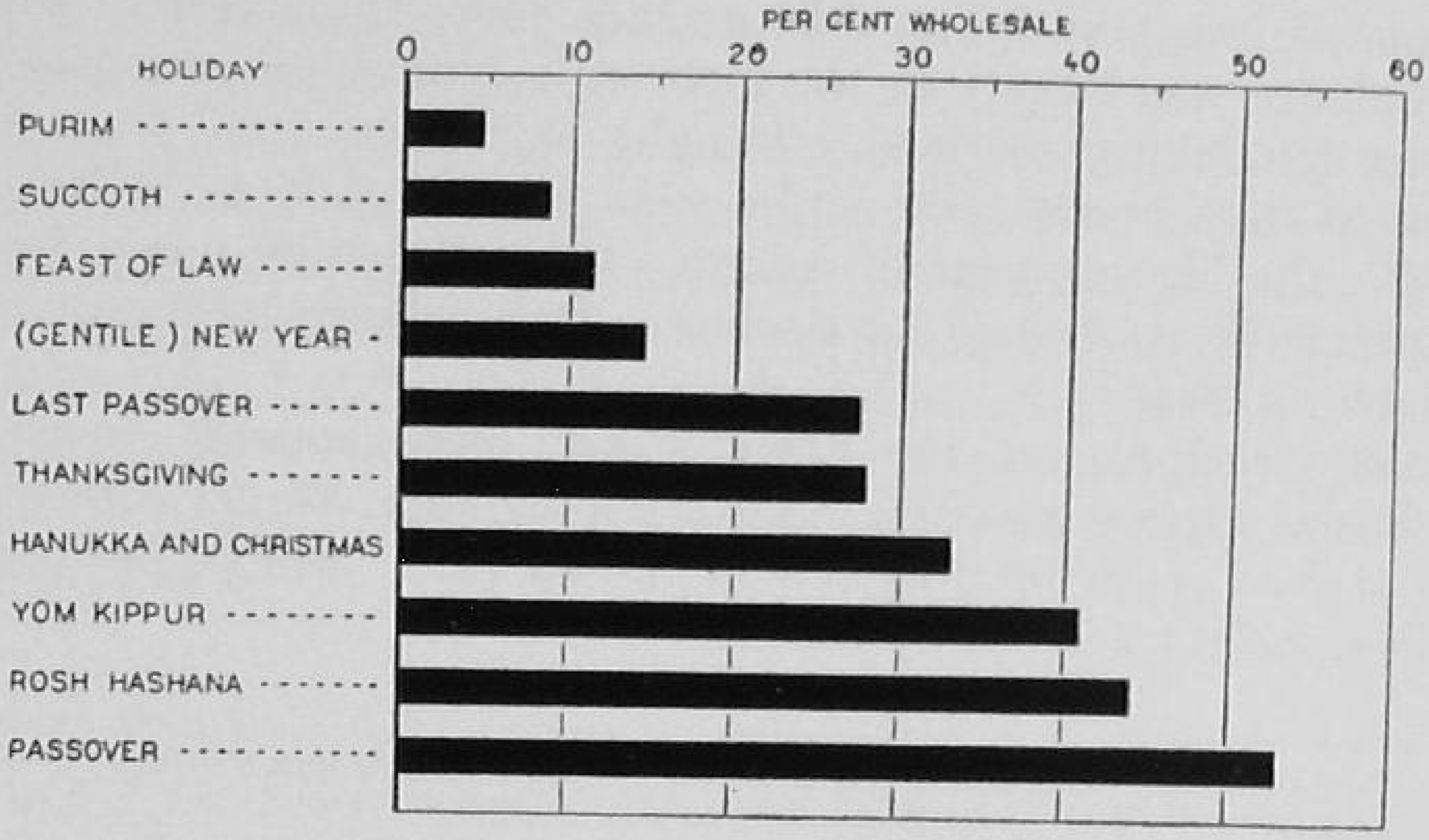


FIG. 192.—Showing the influence of holidays on the weekly sales of live poultry at wholesale in New York City. Increases in sales are here expressed as percentages of the average sales during the two weeks preceding a given holiday. (*After Buechel, 1929.*)

FIG. 193.—A special type of truck designed for hauling live poultry. Soft feed is pumped from the mixing tank to individual feed troughs. (*Courtesy of American Poultry Journal.*)

TABLE 45.—PROPORTION OF RECEIPTS ARRIVING BY RAIL AND BY TRUCK AT FIVE MARKETS, BOSTON, CHICAGO, NEW YORK, PHILADELPHIA AND SAN FRANCISCO, 1944 AND 1949

	1944		*1949*	
Commodity	*Rail*	*Truck*	*Rail*	*Truck*
Shell eggs	47%	53%	19%	81%
Live poultry . .	15	85	2	98
Dressed poultry .	68	32	30	70

TABLE 46.—DATES OF CERTAIN JEWISH HOLIDAYS, 1951–1960

Year	Purim	Pessach (Passover)		Shevuoth (Feast of Weeks)	Rosh Hashanah (New Year)	Yom Kippur (Day of Atonement)	Succoth (Feast of Tabernacles)		Hanukka (Feast of Dedication)
		First days	*Last days*				*First days*	*Last days**	
1951 . .	Mar. 22	Apr. 21–22	Apr. 27–28	June 10–11	Oct. 1–2	Oct. 10	Oct. 15–16	Oct. 22–23	Dec. 24–31
1952 . .	Mar. 11	Apr. 10–11	Apr. 16–17	May 30–31	Sept. 20–21	Sept. 29	Oct. 4–5	Oct. 11–12	Dec. 13–20
1953 . .	Mar. 1	Mar. 31–Apr. 1	Apr. 6–7	May 20–21	Sept. 10–11	Sept. 19	Sept. 24–25	Oct. 1–2	Dec. 2–9
1954 . .	Mar. 19	Apr. 18–19	Apr. 24–25	June 7–8	Sept. 28–29	Oct. 7	Oct. 12–13	Oct. 19–20	Dec. 20–27
1955 . .	Mar. 8	Apr. 7–8	Apr. 13–14	May 27–28	Sept. 17–18	Sept. 26	Oct. 1–2	Oct. 8–9	Dec. 10–17
1956 . .	Feb. 26	Mar. 27–28	Apr. 2–3	May 16–17	Sept. 6–7	Sept. 15	Sept. 20–21	Sept. 27–28	Nov. 29–Dec. 6
1957 . .	Mar. 17	Apr. 16–17	Apr. 22–23	June 5–6	Sept. 26–27	Oct. 5	Oct. 10–11	Oct. 17–18	Dec. 9–16
1958 . .	Feb. 25	Mar. 27–28	Apr. 2–3	May 16–17	Sept. 15–16	Sept. 24	Sept. 29–30	Oct. 6–7	Dec. 7–14
1959 . .	Mar. 24	Apr. 23–24	Apr. 29–30	June 12–13	Oct. 3–4	Oct. 12	Oct. 17–18	Oct. 24–25	Dec. 26–Jan. 2
1960 . .	Mar. 13	Apr. 12–13	Apr. 18–19	June 1–2	Sept. 22–23	Oct. 1	Oct. 6–7	Oct. 13–14	Dec. 14–21

* The last, or ninth, day is also called Simchas-Torah (Feast of Law).

The Jewish feast and fast days greatly influence the demand for live poultry. The principal Jewish holidays come during the early fall and the early spring months, and at these times the quantity of poultry consumed is much greater than usual.

In the New York wholesale market, more poultry is sold on Wednesday than on any other day in the week, the order of importance of the other market days being Thursday, Tuesday, Friday and Monday. The day of greatest slaughter is Thursday in winter and Friday in summer. Fowls have long been the most important class of live poultry dealt in, making up 80 to 85 per cent of the total receipts. Development of the eastern broiler business in recent years has changed all this so that fowls now make up only about one-third of the total.

Shrinkage during shipment from farm to market represents a part of the marketing cost. It varies widely and is affected by such things as air temperature and humidity; age, weight and kind of chickens; the time chickens are on the road; and whether or not they have feed and water available during the trip to market. Records on 100 loads of poultry moving from eastern Connecticut to the New York live poultry market, a distance of about 150 miles, showed shrinks ranging from 8.5 per cent to as low as 1 per cent.

Other Connecticut tests with 14-week-old broilers showed shrinks of 5 to 7 per cent for chickens cooped without feed for 14 hours, compared with 7 to 8 per cent for similar chickens trucked 300 miles during the same length of time. Males showed consistently greater amounts of shrink than did females. Chickens which had been fed high-energy rations fared better than did those fed what had previously been considered standard mixtures. Shrinkage could be estimated roughly as 1 per cent for each of the first two hours plus $\frac{1}{2}$ per cent of the initial weight for each additional hour on the road.

CHAPTER 14

THE BUSINESS OF POULTRY KEEPING

PROFITS in poultry keeping depend mainly on a favorable relationship between the cost involved in producing poultry products and the income received for those products. Some of the items that enter into this relationship are wholly beyond the control of the individual producer, while others can be greatly modified by the adoption of specific practices and methods of management. Both sorts of factors (internal and external) need to be taken into consideration, but it is usually wise for the individual operator to concentrate his attention on those items that will reduce the cost per unit of product, as it is in this direction that he is likely to find the greatest opportunity for increasing his margin of profit.

The General Situation.—The poultry business, like nearly every other productive enterprise, passes through periods of relative prosperity and depression. There are times when the margin between costs and income is so wide that nearly all persons engaged in the business are making money. This sort of relationship attracts others to the industry so that production is soon increased to such an extent as to lower the prices received for the products and to narrow the margin of profit. There are other times when the major items of cost are so high in relation to the prices received for poultry and eggs that only the most efficient operators can make a profit.

There are various ways of measuring this relationship and of indicating the relative position of poultry and egg producers at any given time, but because feed cost represents such a large part of the total cost of production, it is convenient to make use of an egg-feed ratio, or a poultry-feed ratio, or some combination of the two, in presenting the general situation.

One method is to calculate the number of dozens of eggs of a specified grade required to purchase 100 pounds of a specified feed mixture. Another is to calculate the number of pounds of a given feed mixture that one dozen eggs will buy at different times. Still another is to use the normal or expected egg production of a hen in one year, or a combination of the number of eggs and pounds of chicken which will normally be sold in one year for each hen in the flock, and to calculate the quantity of feed for which they can be exchanged at any particular time. Index numbers of egg, feed, and poultry prices may be compared to give a picture of relative prosperity in the poultry business.

Following a period of favorable egg-feed price relationships there is likely to be temporary overproduction with consequent lower prices of poultry products. If this happens to occur just at the beginning of a sharp rise in the general price level, or just prior to a year of general crop failure, with resulting higher feed costs, even the most efficient poultry and egg producers will find conditions extremely difficult for a time.

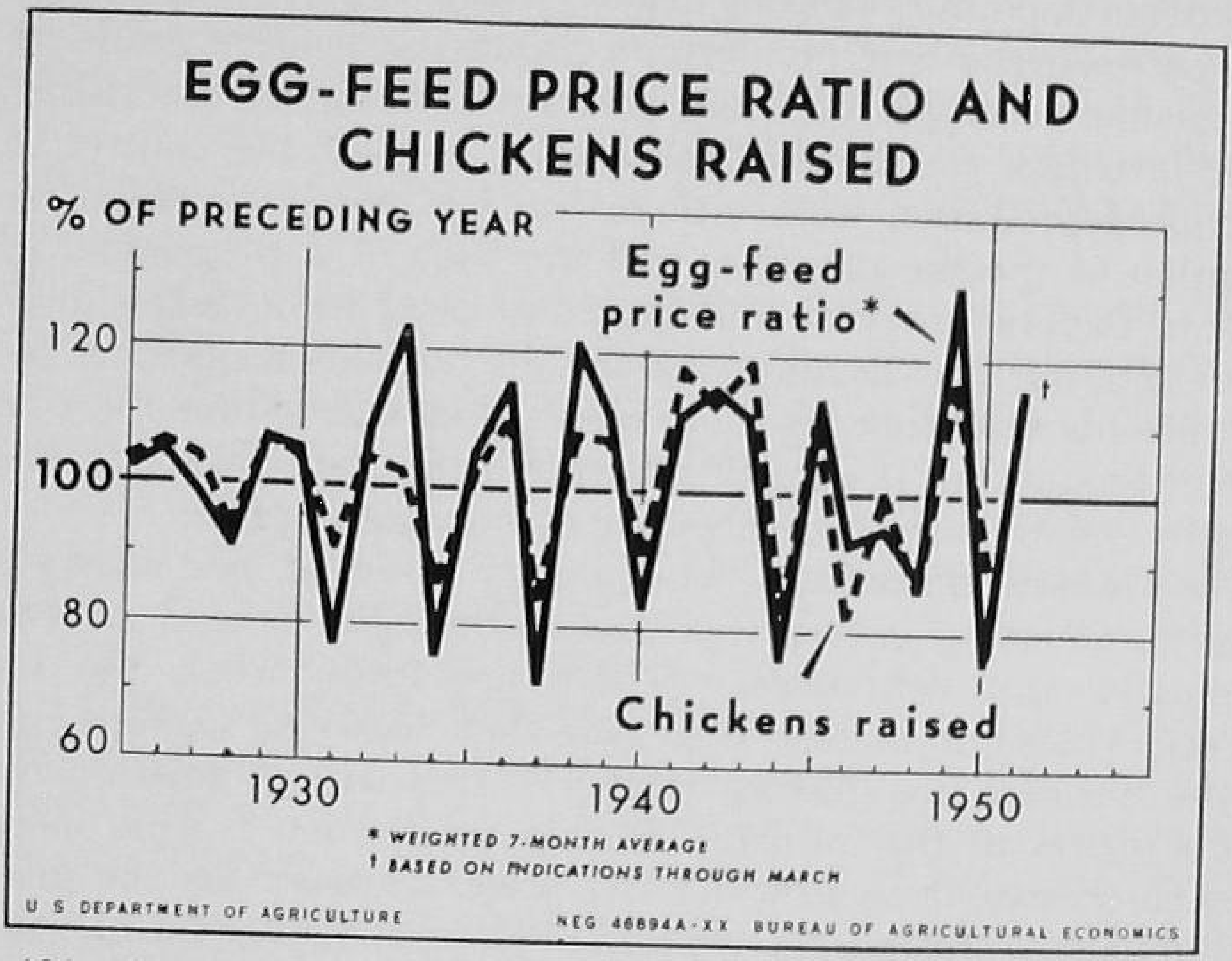


FIG. 194.—Changes in the egg-feed price ratio affect the number of chickens raised each year.

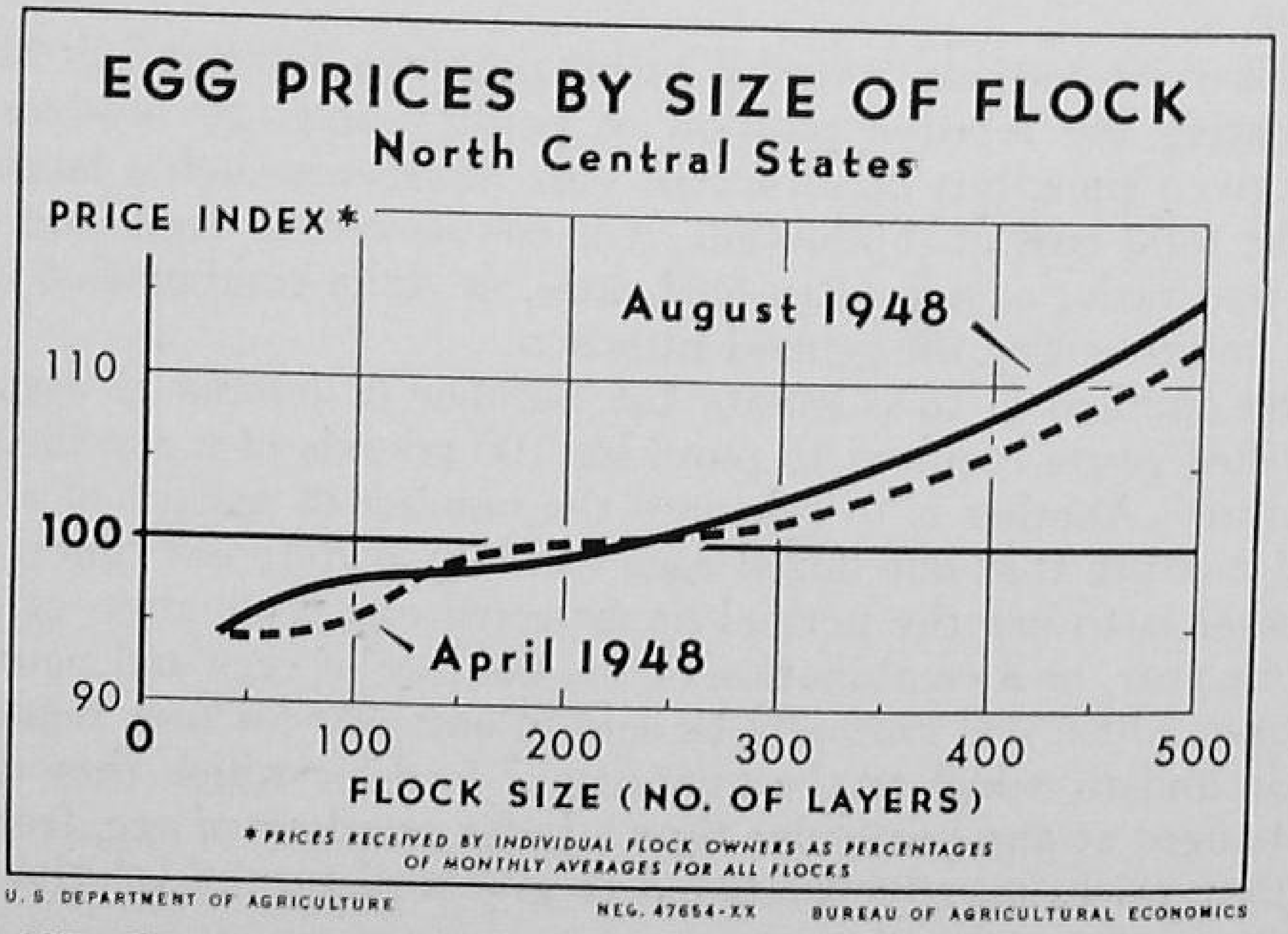


FIG. 195.—Owners of large flocks usually enjoy some price advantage when they send their eggs to market.

The Effect of Location.—In addition to the economic advantage that may come from a favorable price relationship between cost and income items, as they vary with time, there is the type of economic advantage which results from being in a geographical location that is favorable to poultry and egg production. This may depend upon a freight differential in comparative feed or egg and poultry prices, or it may depend upon the effect of surplus

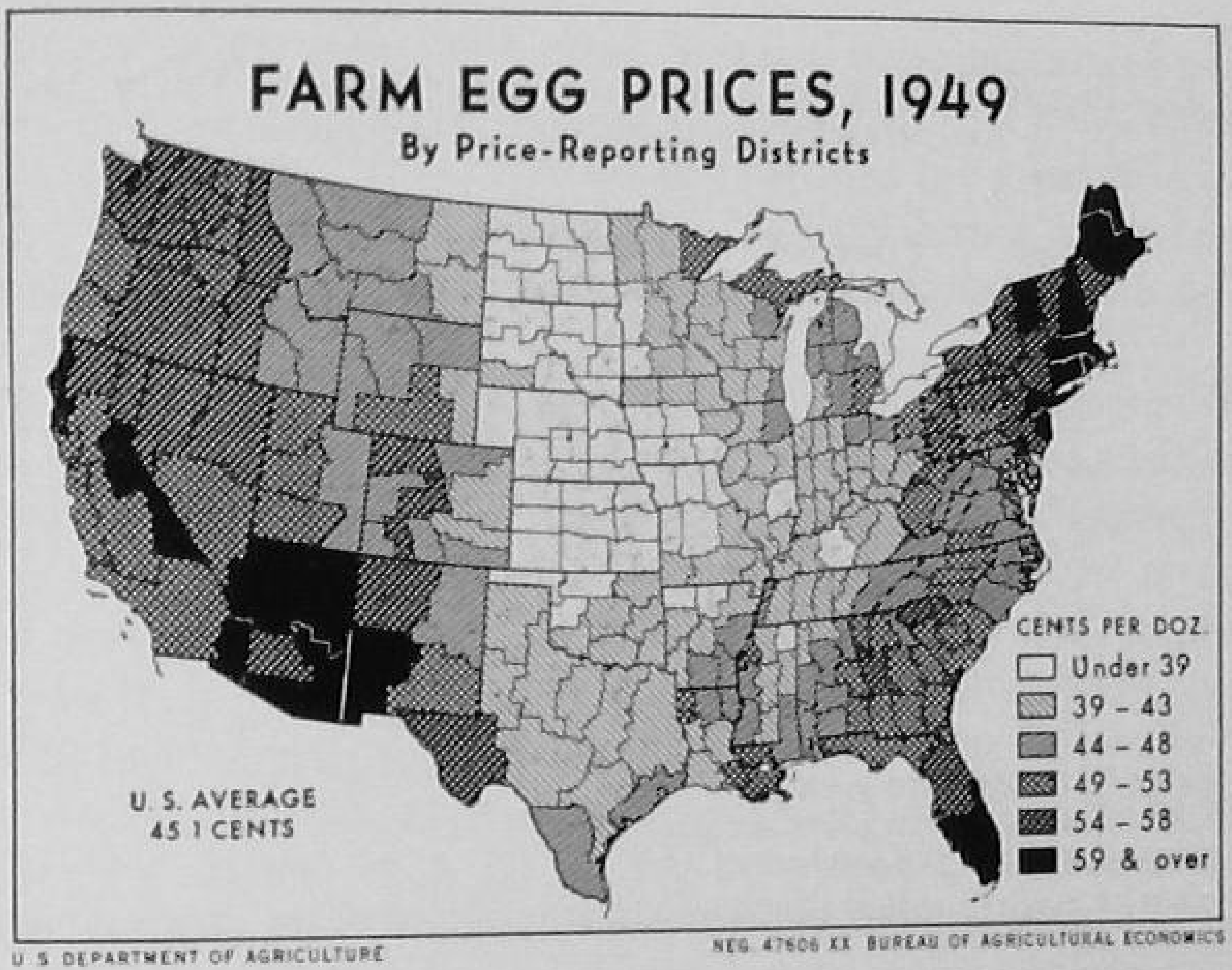


FIG. 196.—Eggs command a better price in some sections of the country than in others, as clearly indicated by this map.

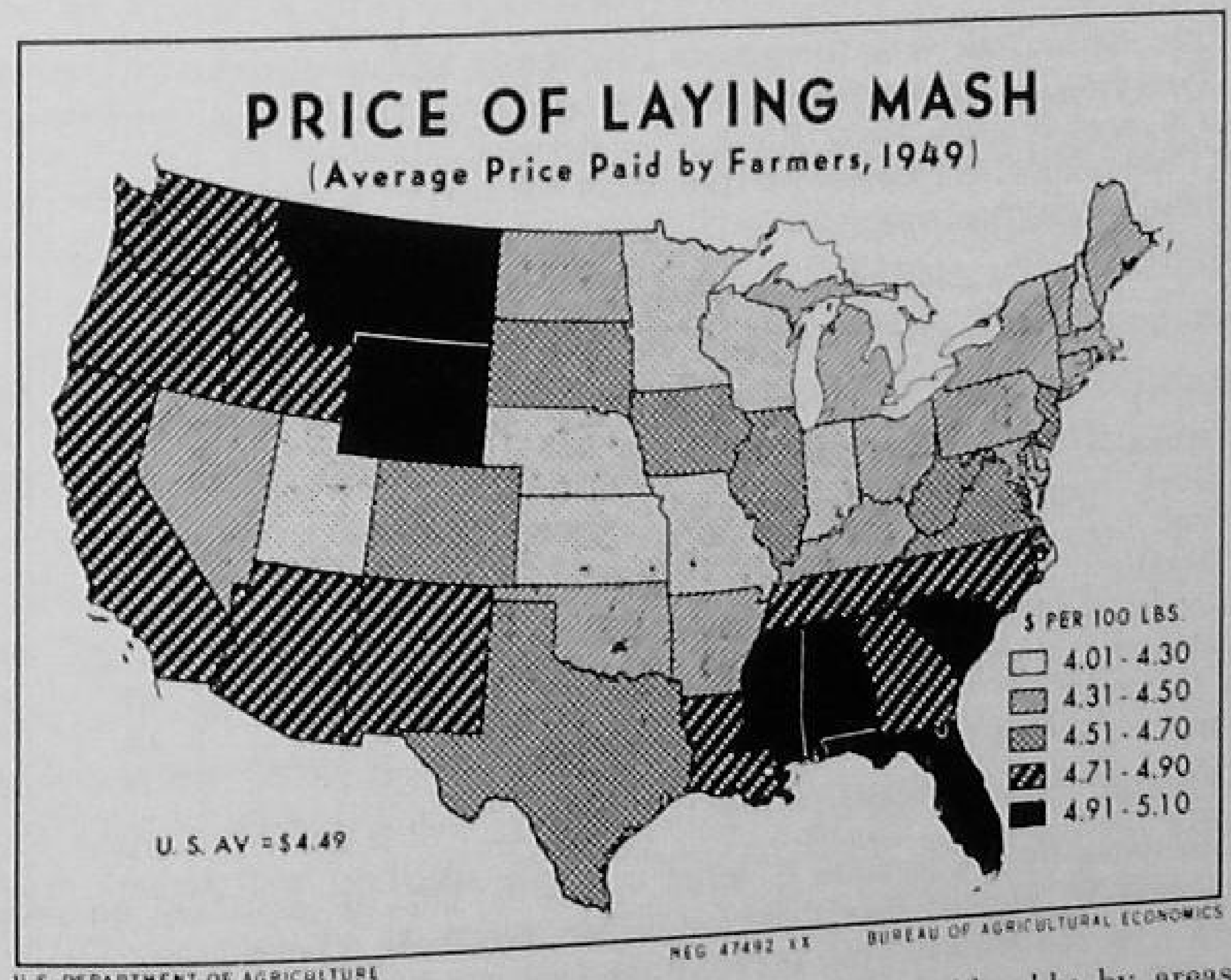


FIG. 197.—The average cost of poultry feed varies considerably by areas as shown by this map which indicates the average price of laying mash in 1949.

or deficit areas in lowering the price of feed or raising the price of poultry products with little relation to transportation costs. Thus in the more densely populated sections of the country the farm price of eggs and of chickens takes on some of the characteristics of a retail price, because many more sales are made direct from producer to consumer, or from producer to jobber. The cost of feed in deficit areas is not so likely, as is the price of eggs, to be above that in surplus areas by more than the difference due to

TABLE 47.—PRICES OF CHICKENS, EGGS AND POULTRY FEED, BY YEARS, 1941–1950, AS REPORTED BY THE U. S. DEPT. OF AGRICULTURE

Year	*Eggs*[1] *(cents)*	*Chickens*[2] *(cents)*	*Poultry ration*[3]	*Egg-feed ratio*[4]	*Chicken-feed ratio*[5]	*Baby chicks (per 100)*[6]
1941	23.5	15.8	$1.83	13.5	8.5	$ 9.01
1942	30.0	19.0	2.21	14.2	8.5	11.33
1943	37.1	24.5	2.66	14.5	9.1	13.90
1944	32.5	24.0	2.94	11.5	8.2	15.00
1945	37.7	26.1	2.91	13.4	8.9	15.50
1946	37.5	28.0	3.47	11.3	7.7	15.70
1947	45.3	26.8	4.15	11.1	6.5	16.40
1948	47.2	30.6	4.29	11.4	7.0	18.70
1949	45.2	25.7	3.46	13.2	7.7	19.40
1950	36.2	23.4	3.58	10.3	6.4	18.80

[1] Weighted average farm price per dozen.
[2] Weighted average farm price per pound.
[3] Average cost per 100 pounds.
[4] Pounds of poultry ration equivalent in price to one dozen eggs, average of 12 monthly values.
[5] Pounds of poultry ration equivalent in value to one pound of chicken, average of 12 monthly values.
[6] Season average to May 1.

TABLE 48.—FARM PRICES OF BOTH EGGS AND FEED ARE INFLUENCED BY GEOGRAPHICAL LOCATION, AS SHOWN BY THE FOLLOWING DATA FOR 1950. EGG PRODUCTION ALSO VARIES WIDELY FROM REGION TO REGION. (PRICES OF FEED AND EGGS, AND PRODUCTION PER LAYER AS REPORTED BY THE U. S. DEPARTMENT OF AGRICULTURE.)

Region	*Eggs per layer*	*Farm price per dozen*	*Pounds of feed per layer**	*Cost of ration per 100 lbs.*	*Value of eggs per layer*	*Cost of feed per layer*	*Difference*
North Atlantic	187	47.8¢	91.7	$4.13	$7.44	$3.79	$3.65
East North Central	174	33.7	89.8	3.49	4.88	3.10	1.68
West North Central	172	29.1	89.6	3.25	4.17	2.91	1.26
South Atlantic	145	40.5	85.7	4.06	4.89	3.48	1.41
South Central	137	33.0	84.6	3.70	3.77	3.13	.64
Western	182	41.2	91.0	3.90	6.25	3.55	2.70
United States	167	36.2	88.8	3.62	5.04	3.21	1.83

* Calculated by the formula $F = 25 + 8W + E/7$, as explained on page 244. The value of W, average weight of hens, is assumed to be 5 pounds.

NOTE: On the basis of 1949 prices, when feed cost was 3 per cent lower and egg prices were 25 per cent higher, the values in the last column become $5.16, $3.13, $2.77, $2.53, $1.74, $4.05 and $3.17.

transportation. The final result is a greater difference between cost and income for the poultryman located near the centers of population than exists for the producer who is several hundred miles away. The margin in seven different regions of the United States, calculated from production and price data reported by the U. S. Department of Agriculture, is shown in Table 48.

POULTRY ON THE GENERAL FARM

In many sections of the United States the production of poultry and eggs is now considered to be an essential part of a well-diversified system of farming. This is particularly true in the great Mississippi Valley area where large commercial poultry farms are relatively few and far between, but where nearly every farmer has a flock of hens.

The income from poultry very often furnishes a large part of the living for the farm family, but because the income is distributed in small amounts throughout the year, its total significance is not always realized, and the flock frequently does not get the attention that it deserves. Merely to increase flock size under such conditions may result in a greater cash outlay without any corresponding increase in returns. Consideration of this problem naturally leads to such questions, as, How can an individual farmer best determine whether he should keep 50 or 500 hens as a poultry enterprise? Should a 160-acre farm have more or fewer hens than an 80-acre farm? Is there any definite relation between size of farm and size of poultry flock, and if so, what is the probable limit of flock size for each size of farm?

Size of Flock.—There will always be a place for the family flock, large enough to provide eggs and meat for the farm family, with some surplus at certain seasons of the year. If, however, the poultry enterprise is to be an efficient part of a diversified farm business it must be considerably larger than the average family flock, and should probably contain a minimum of 400 hens. Such a flock is large enough to make it profitable to follow the best management practices, whereas with smaller flocks there is always some question as to the profitableness of many practices that are known to pay under commercial or semi-commercial conditions. It is the "middle-sized" flock that is likely to be inefficient.

The Importance of Egg Yield.—Average yearly egg yield has a decided influence on the income realized from the poultry flock. This has been clearly shown by a number of independent studies. Higher egg yields usually mean higher expenses, but the income per hen increases enough more rapidly than expenses to show a net return decidedly in favor of the higher producing flocks. The data in Table 49, based on records of 160 farm flocks in Minnesota in 1949, show the essential relationships.

it is a minor consideration. Commercial egg producers commonly choose Leghorns because the slightly lower feed and housing cost per head becomes significant when a large flock is maintained. Another reason is that very few Leghorns go broody. Then, too, they lay white eggs that bring a premium price on some markets. Some flock owners object to dark colored fowls such as Rhode Island Reds because they absorb so much light that they make the pens or houses seem very dark.

Under the conditions that prevail on the general farm, or whenever the number of hens kept is under 400, there is little reason for recommending one breed over another. The personal choice of the owner should be the first consideration, though it is often true that poultry meat income from the farm flock can be made of sufficient importance to warrant the owner in choosing one of the medium-weight or general-purpose breeds. The quality of stock, as determined by breeding, is always more important than the particular breed or variety selected.

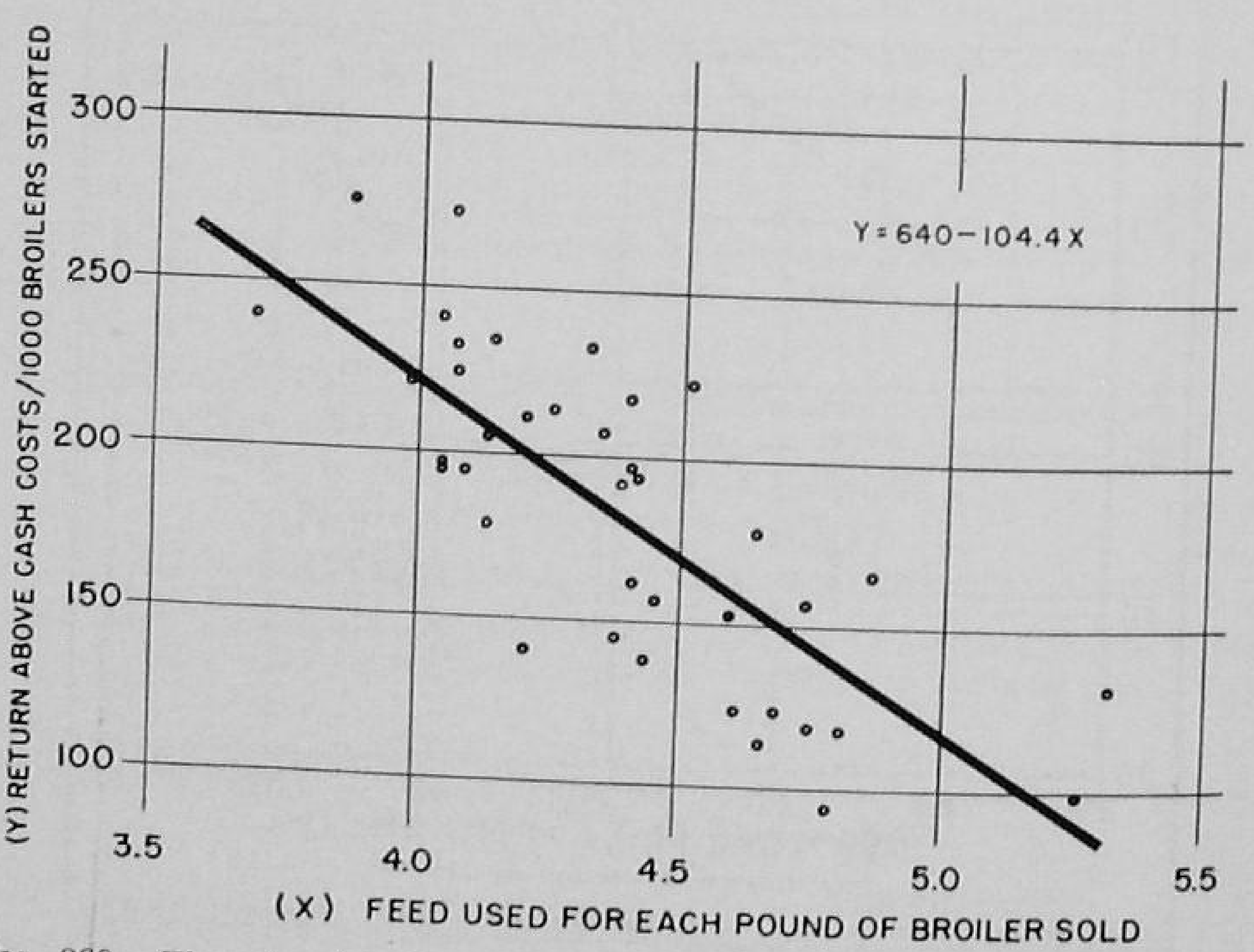


FIG. 200.—The rate of feed conversion is an important factor in determining returns in broiler growing. Plotted points indicate the feed conversion for each of 39 broiler growers all of whom had the same kind of chicks and all of whom used the same brand of feed. (*Prepared from data of Hammond, 1950.*)

BROILER PRODUCTION

The proportion of the total chicken meat supply furnished by commercial broilers has risen steadily from about 5 per cent in 1935 to nearly 50 per cent in 1951. During the same period the trend in broiler prices, expressed as a percentage of the farm prices of all

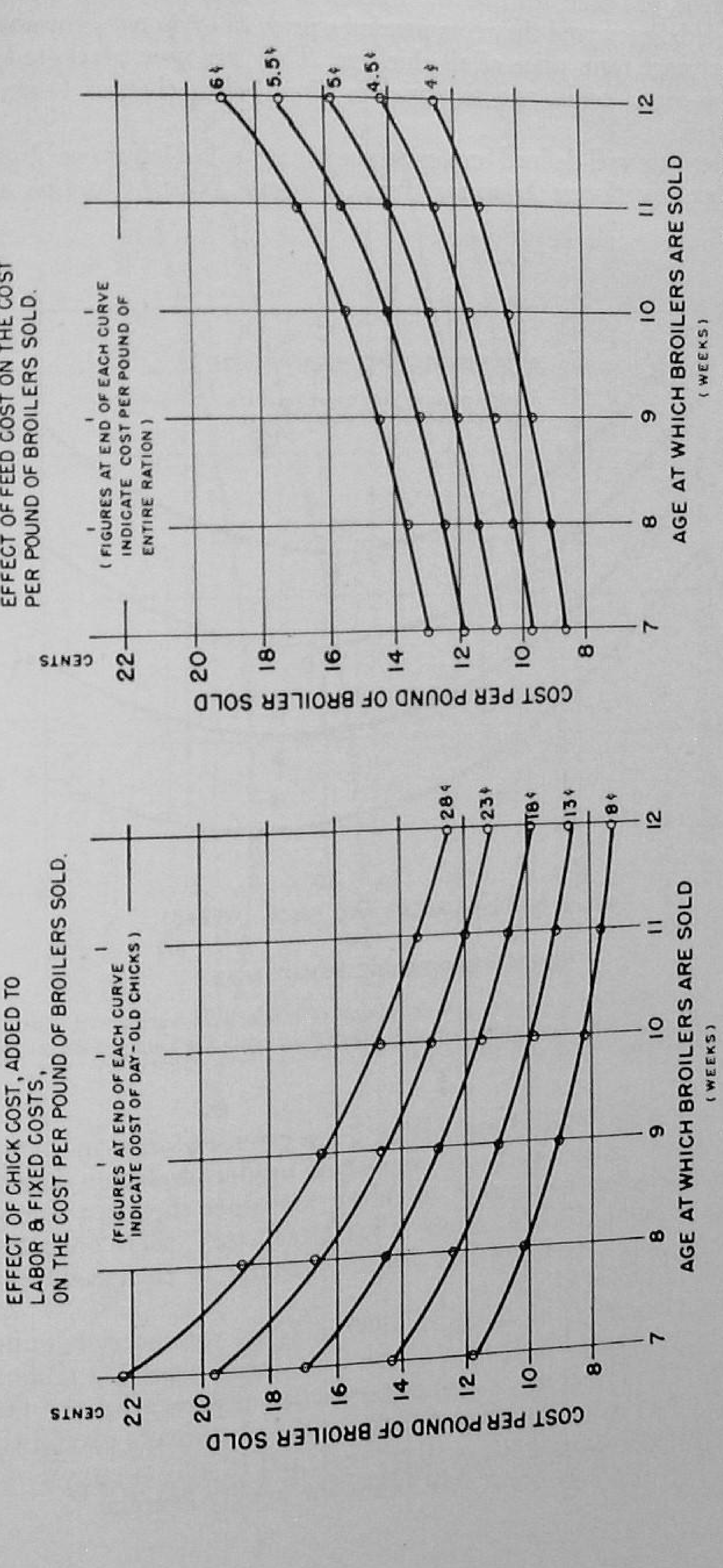


Fig. 201.—Showing the effect of chick cost and of feed cost on the cost per pound of broiler sold at different ages. To find total cost, add the values for selected points on the two parts of this chart. See text for discussion. The data are given in Table 53.

chickens, has been downward. Fifteen or twenty years ago broilers were a delicacy, and they commanded a price 25 or 30 per cent above the average farm price of all chickens. They are now marketed on a year-round basis, and the price is often below that of fowls or roasters.

There are well-defined broiler-producing areas in Delmarva, North Georgia, Northwest Arkansas, Texas, Virginia, North Carolina and

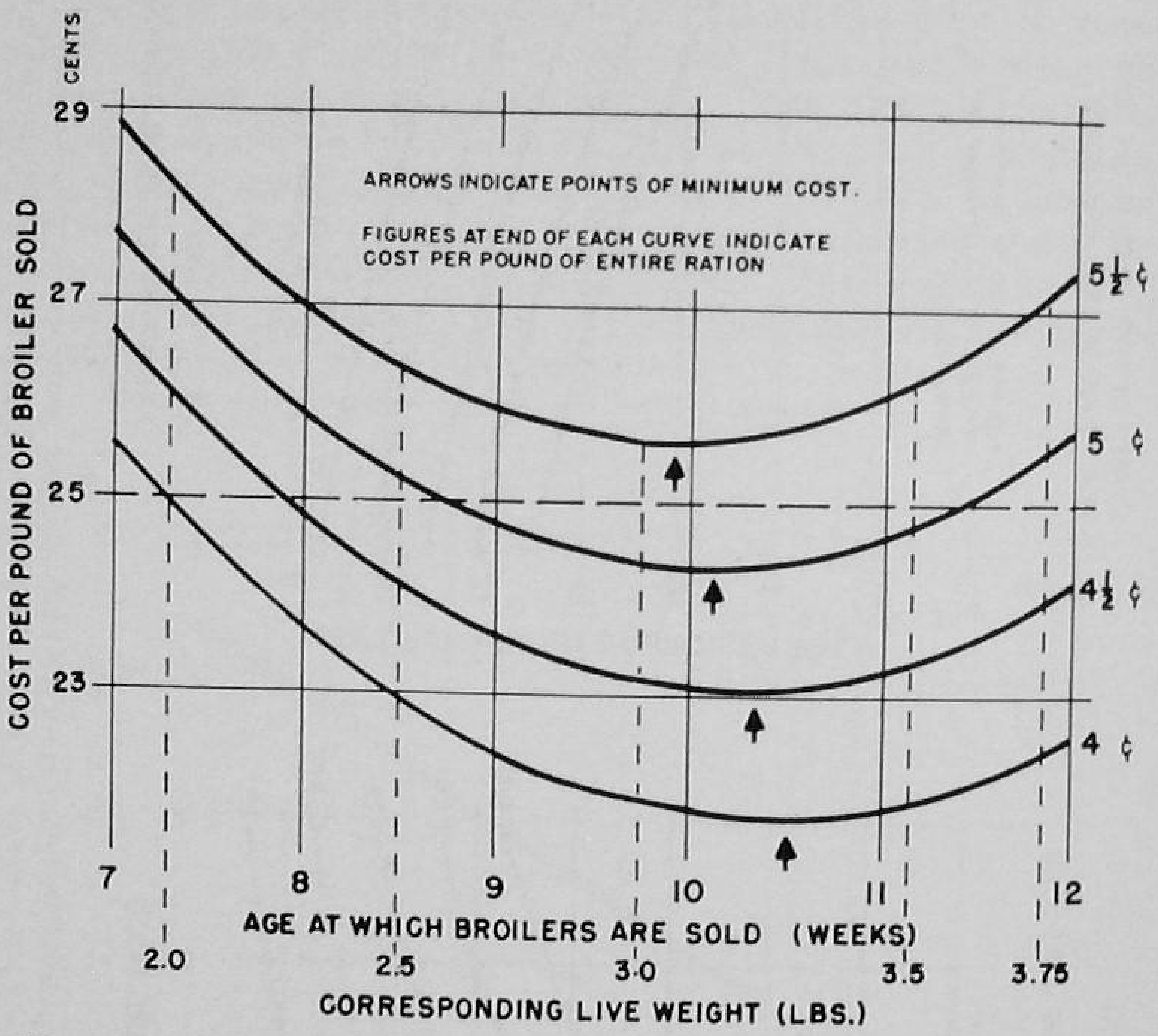


FIG. 202.—Showing how total cost per pound of broiler sold varies with age and cost per pound of feed when chick cost and other fixed costs are held constant. See text for discussion, and Table 53 for data.

in parts of New England, and similar if less extensive areas in several other states. Since nearly all commercial broiler producers depend on hatcheries for their supply of chicks, and since they can change sources promptly if performance is not satisfactory, there are many hatcheries and breeding farms which specialize in the production and sale of broiler chicks.

Total placements of chicks in 1950 in seven commercial broiler areas representing 55 per cent of the U. S. total, were 370 million. The year-round nature of broiler production is shown by the fact that in only three weeks during the year did placements exceed the weekly average by as much as 10 per cent, and in only six weeks did they fall as much as 10 per cent below the weekly average.

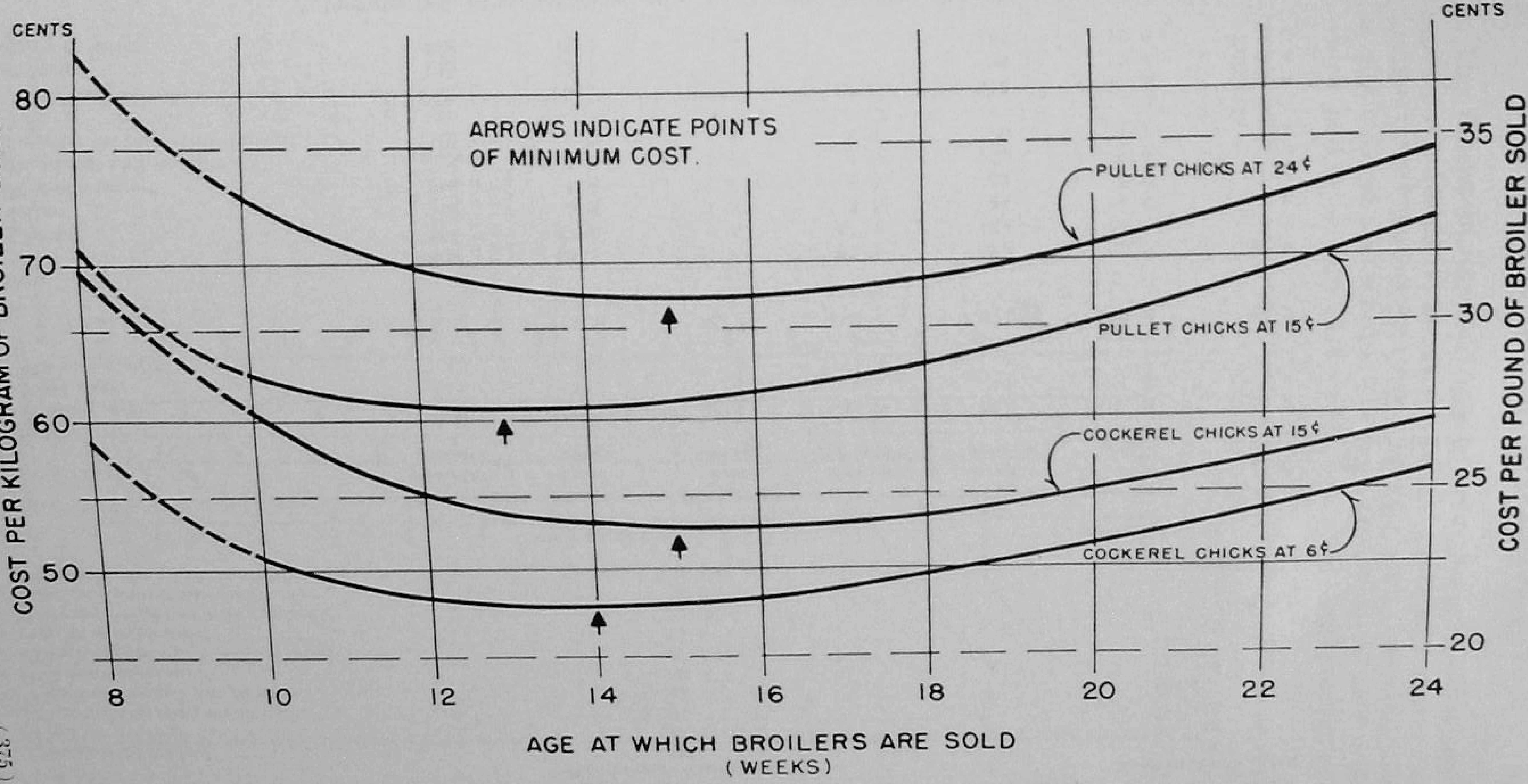


Fig. 203.—Showing how total cost per pound of broiler sold varies with age, sex and cost per chick when feed and other costs are held constant. See text for discussion. The data are given in Table 54.

cluding the effect of variable feed wastage and of mortality. The average weight at which these broilers were sold was 3.06 pounds, and only about one-fourth were sold at weights as much as 5 per cent above or below this average. Each plotted point in the diagram represents an average for the 7 to 9 lots raised by each grower. The equation of the regression line, which was fitted by the method of least squares, is $Y = 640 - 104.4X$. In this equation Y is dollars returned above cash costs for each 1000 chicks started, and X is the feed used for each pound of live broiler sold.

Average feed conversion is much better with the rations commonly used in 1950-51, and most broilers can therefore be marketed at ten to eleven weeks of age, but wide variation still exists. Successful operators have learned to depend on the kind of chicks that grow rapidly, and to keep both feed wastage and mortality at a minimum.

TABLE 53.—AN APPROXIMATE STANDARD FOR GROWTH AND FEED CONSUMPTION FOR MIXED COCKERELS AND PULLETS GROWN AS BROILERS OR FRYERS. (THESE DATA WERE USED IN PREPARING FIGURES 201 AND 202.)

Age in weeks	*Average weight (pounds)*	*Cumulative feed consumption (pounds)*	*Labor and fixed costs* per head (cumulative) (cents)*
1	.16	.25	26.05
2	.32	.55	27.10
3	.54	.95	28.15
4	.80	1.45	29.20
5	1.10	2.10	30.25
6	1.45	3.10	31.30
7	1.90	4.10	32.35
8	2.30	5.20	33.40
9	2.70	6.50	34.45
10	3.10	8.00	35.50
11	3.45	9.70	36.55
12	3.80	12.00	37.60

* Chicks at 18¢ each
Other fixed costs at 7¢ per chick started
Labor at $1.50 per day per 1000 chickens

In attempts to explain why such differences occur, and to point the way to better management practices, cost records are frequently sorted in various ways to show the effect of certain selected factors. For example, the records of the 315 lots of broilers shown in Tables 50 and 51 have been resorted as shown in Table 52 according to age and average weight at time of sale. Sorts of this kind are helpful in showing what happens to different groups of growers, but they still do not explain why the differences occurred, and they may sometimes lead broiler operators to make wrong decisions or to adopt unprofitable practices.

What is needed is a breakdown which will show how the accumulated cost is changing from week to week, or with each added fraction of weight, so that an individual producer can have a reasonable

basis for deciding when to sell. Not many data of this kind are available, but Tables 53 and 54, and Figures 201, 202 and 203 prepared from them, will serve as examples.

TABLE 54.—COMPARATIVE GROWTH AND FEED CONSUMPTION OF COCKERELS AND PULLETS. DATA OF JULL AND TITUS, 1928: JOUR. AGR. RES., 36, 541–550. (THESE DATA USED IN THE CONSTRUCTION OF FIGURE 203.)

	Cockerels		*Pullets*	
Age in weeks	*Average weight (grams)*	*Cumulative feed consumption (grams)*	*Average weight (grams)*	*Cumulative feed consumption (grams)*
8	—	—	—	—
10	916	2,860	814	2,445
12	1,265	4,148	1,058	3,621
14	1,604	5,555	1,289	4,878
16	1,884	6,864	1,493	6,129
18	2,194	8,511	1,683	7,446
20	2,472	10,227	1,875	8,981
22	2,716	11,972	2,043	10,541
24	2,927	13,736	2,193	12,154

Cost figures used in constructing Figure 203:
Straight-run chicks @ 15¢ each
Cockerel chicks @ 6¢ each
Pullet chicks @ 24¢ each
Feed @ $90 a ton (10¢ a kilogram)
Labor @ $1.00 a day for each 1000 chickens
Other fixed costs—5¢ for each chick started

Mortality is not separately considered. Early mortality would have little effect because (1) Chick cost and other fixed costs are already included, and (2) Up to four weeks of age feed cost is only about ⅓ of the total fixed costs, including chicks. Late mortality is a special problem in any case and may remove any chance for profit.

An inspection of the curves shows that the higher the cost of feed, the earlier broilers must be sold if the grower is to obtain the maximum margin over feed cost per pound. On the other hand, high fixed or initial costs, such as a high price paid for chicks, make it necessary to sell at a later time (in terms of age or weight) in order to distribute these costs over more pounds of broiler and thus obtain a maximum margin. One set of costs increases, and the other decreases, the longer the chickens are kept, and the broiler grower is faced with the nice problem of deciding for each lot he raises when the combination of the two is at a minimum. The whole problem is often further complicated by the prospect of a declining market.

The chart shown in Figure 204 brings together the relationships shown in Figures 201 and 202 so that their combined effect can be determined. On the basis of the growth, feed consumption and other cost data shown in Table 53, it is possible to determine for any chick cost and any cost of feed the age at which to sell broilers for the maximum margin per pound. This chart is based on mixed sexes or straight-run chicks. For lots of broilers which have a different rate of feed conversion, the final result might be quite different.

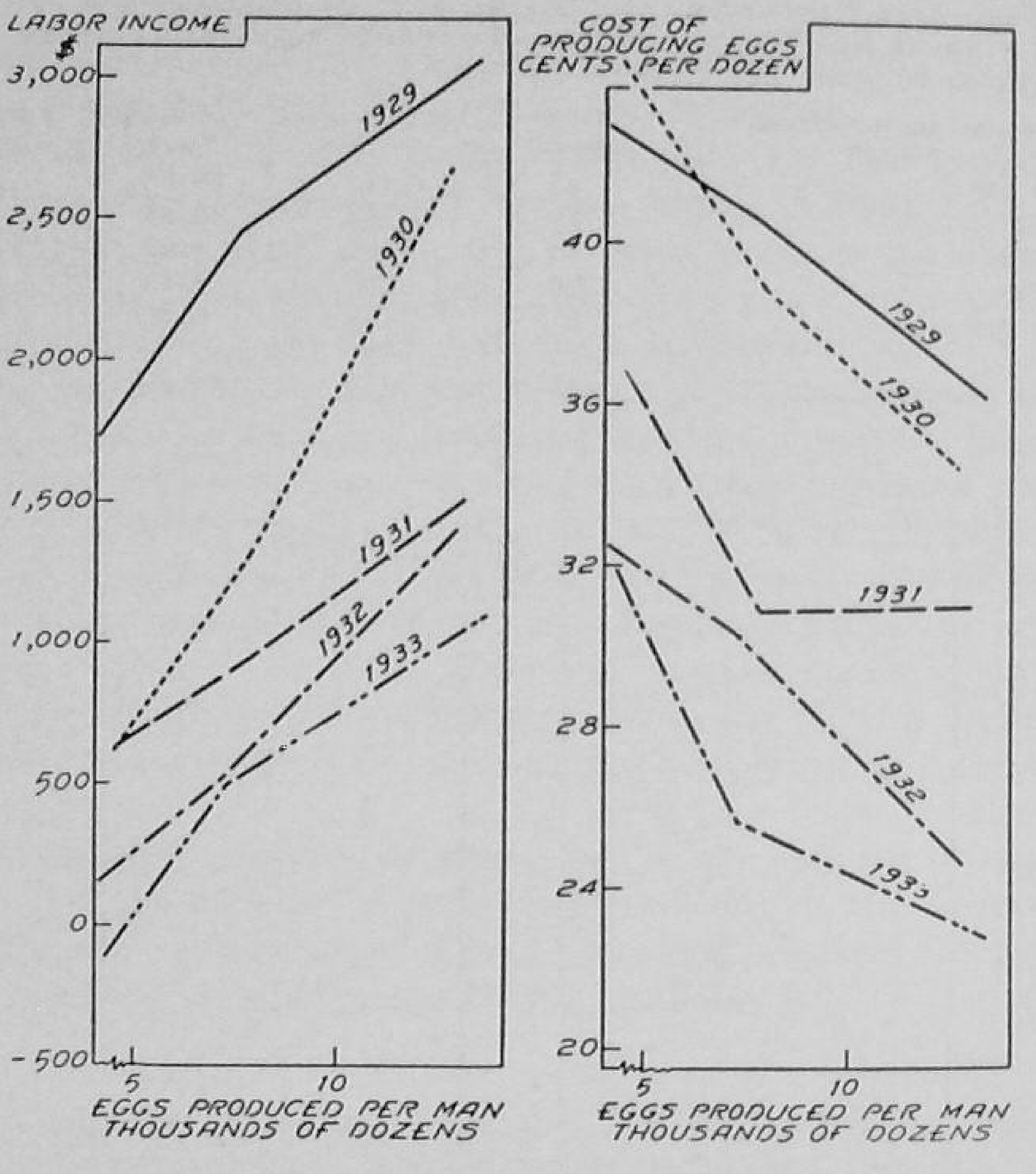


FIG. 207.—Relation of dozens of eggs per man-year to labor income and to cost of producing eggs. (*Courtesy of Cornell Agricultural Experiment Station.*)

FIG. 208.—Labor efficiency can be increased by the use of large doorways, and by interior arrangements which permit driving through long poultry houses.

24 cents, and 20 cents. Curves showing how feed per dozen eggs varies with egg production of 4½- and 5½-pound hens are presented in Figure 209.

Labor Efficiency.—Efficient use of labor is important on poultry farms because, as has already been stated, the number of hens kept has a great deal to do with the size of the farm income. For maximum labor efficiency it is necessary also to have good stock, because a high egg yield per hen makes possible the production of a large number of eggs per man. Eggs produced per hour of man labor, or per man employed per year, can be used as an index of labor efficiency. Tables 63 and 64 show this sort of comparison for poultry farms in New York and Oregon, respectively.

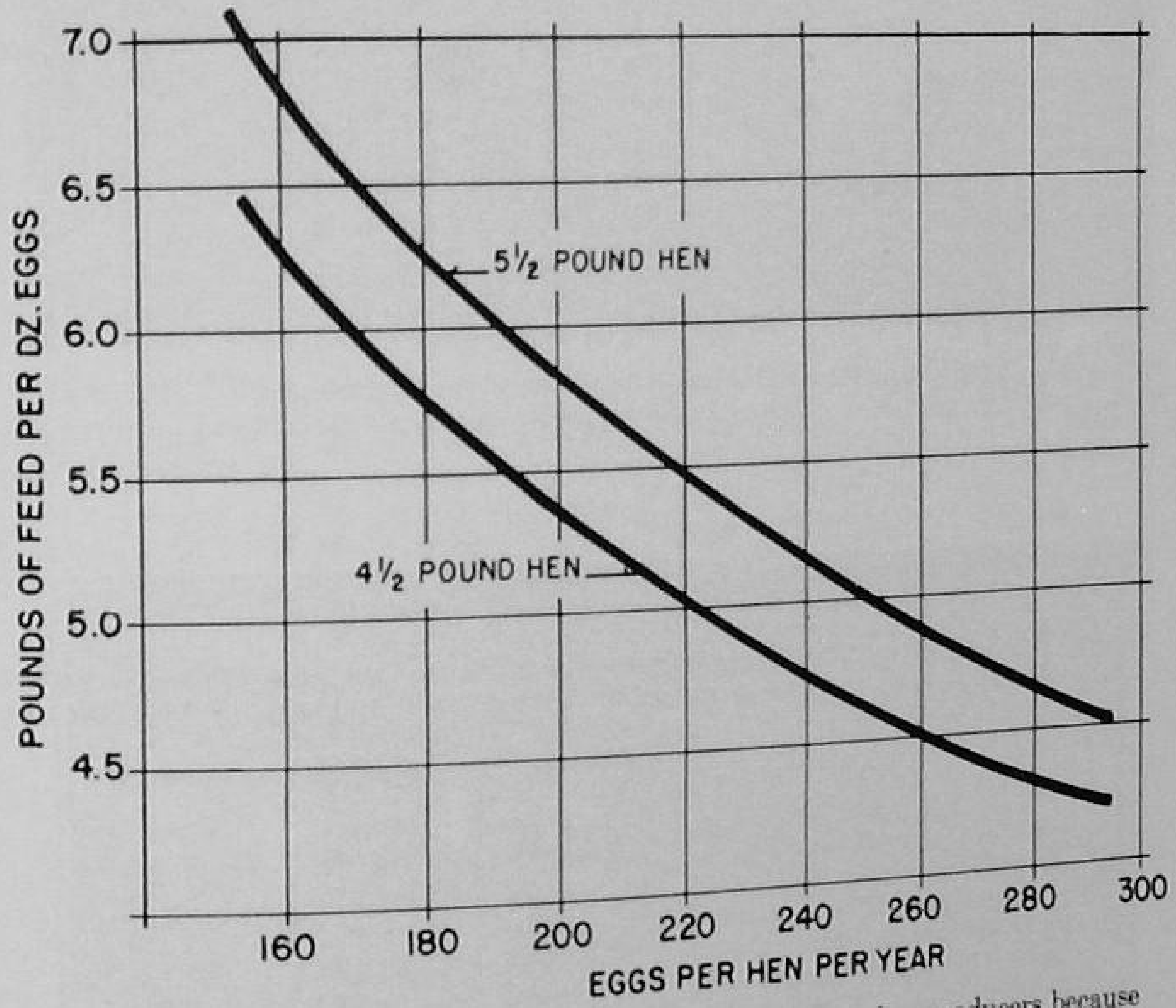


FIG. 209.—High-producing hens are more profitable than low producers because they require less total feed for each dozen eggs laid.

A common cause of low efficiency in the use of labor is the route of travel in doing the necessary daily chores connected with the poultry enterprise. In a study made in Oregon, summarized in Table 64, it was found that the long-distance men on measured chore routes traveled seven to fourteen times as far as the short-distance men. Time saved in chore-route travel can be better expended in taking care of more hens or in finding additional ways to cut costs or increase market returns.

In a study of labor saving on Pennsylvania poultry farms it was found that installation of automatic watering systems saved nearly

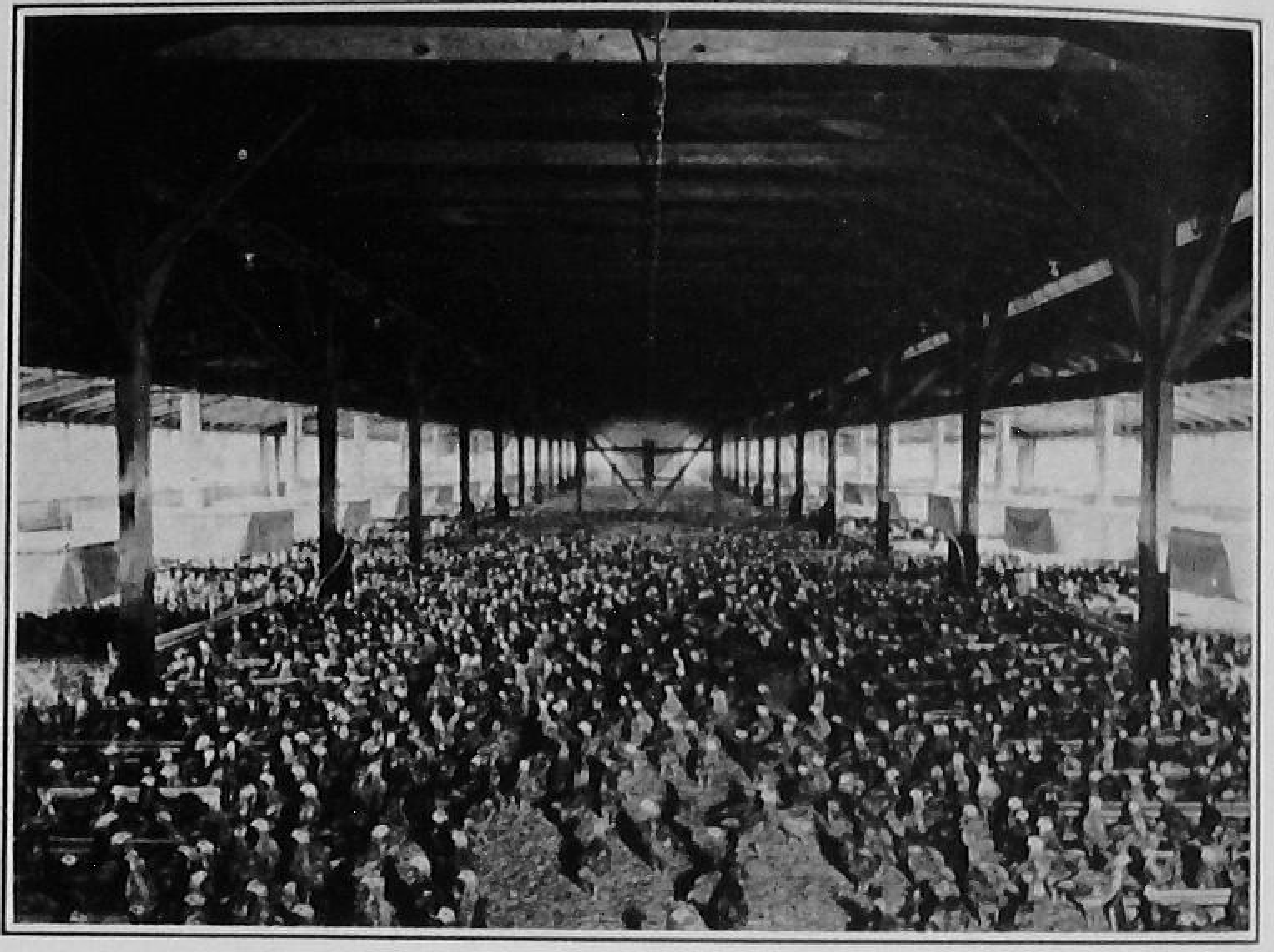


FIG. 212.—Many broiler growers prefer the conventional type of feeder. Note hovers at right and left, supplied with forced warm air while chicks are small. *(Courtesy of U. S. Egg and Poultry Magazine.)*

FIG. 213.—A motor-driven conveyor belt saves labor when cleaning out old litter. *(Courtesy of American Poultry Journal.)*

Bulk delivery of feed is a service which is becoming more widely available to poultrymen in many parts of the country. Full use of this system permits substantial savings in both feed cost and in labor.

Mortality and Flock Depreciation.—One of the most serious problems confronting poultrymen in many sections of the country is the mortality among laying pullets, and to a less extent among older hens. Methods of sanitation, as previously pointed out, have enabled flock owners to bring the mortality of young growing chickens reasonably well under control, but the problem of reducing or preventing excessive mortality of laying stock is not yet completely solved. It appears that the most promising method of attack is through breeding and selection for highly resistant strains, but until the vital significance of the problem is fully appreciated, progress is likely to be rather slow.

To the beginner in poultry keeping, the loss of a few fine pullets is little short of tragedy, but the more experienced operator accepts a certain mortality as a matter of course, and looks upon the picking up and disposal of dead hens merely as one of the chores. The practical result is that poultrymen have become accustomed to a mortality loss that would not be tolerated at all in any other livestock business. As long as there was a profit left to the individual operator little was said about the loss, and in the meantime the total cost to the industry has been tremendous.

Mortality among laying flocks not only causes a direct monetary loss amounting to the value of the birds that die, but it results in further indirect losses that may be even more costly in spite of the fact that they are less apparent. Houses, equipment and labor sufficient to care for 1200 hens will be used with decreasing efficiency as the death loss mounts during the year. This is partly obscured by the common practice of making calculations, such as average egg yield, on the basis of the average number of layers in the flock during the year, or on the hen-day basis. A flock that has lost 50 per cent of the original number by death may thus show an average yield well above 200 eggs. If all such calculations were made on the basis of the number of hens and pullets at the beginning of the laying year the picture would often be quite different.

The mortality among commercial flocks observed in some of the economic studies of poultry farming that have already been cited was 7 per cent in New Jersey in 1915-1916; 13 per cent in Oregon in 1926-1928; 17 per cent in New Hampshire in 1929-1930; 20 per cent in Utah in 1929-1931, and 25 per cent in New York in 1940-1941.

Fortunately there has been substantial improvement in this respect in recent years, and many commercial farms now experience a death loss of no more than 10 per cent. If this is distributed uniformly through the year, the effect on the cost of producing eggs is

small, especially with Leghorns or other light breeds with relatively small market value when sold for meat. The difference between the inevitable depreciation and total loss by death is not very great.

Even if the pullets all lived through the first twelve months in the laying house, they would be worth less after a year of production than at the beginning. As potential egg-producers they are worth more when about six months old and ready to lay than at any other time. The normal expectation is that they will continue to be worth less and less as they get older, until their egg-laying value is equal to their meat value. This does not take into account the possible breeding value of certain individuals, but is concerned only with their value as egg layers.

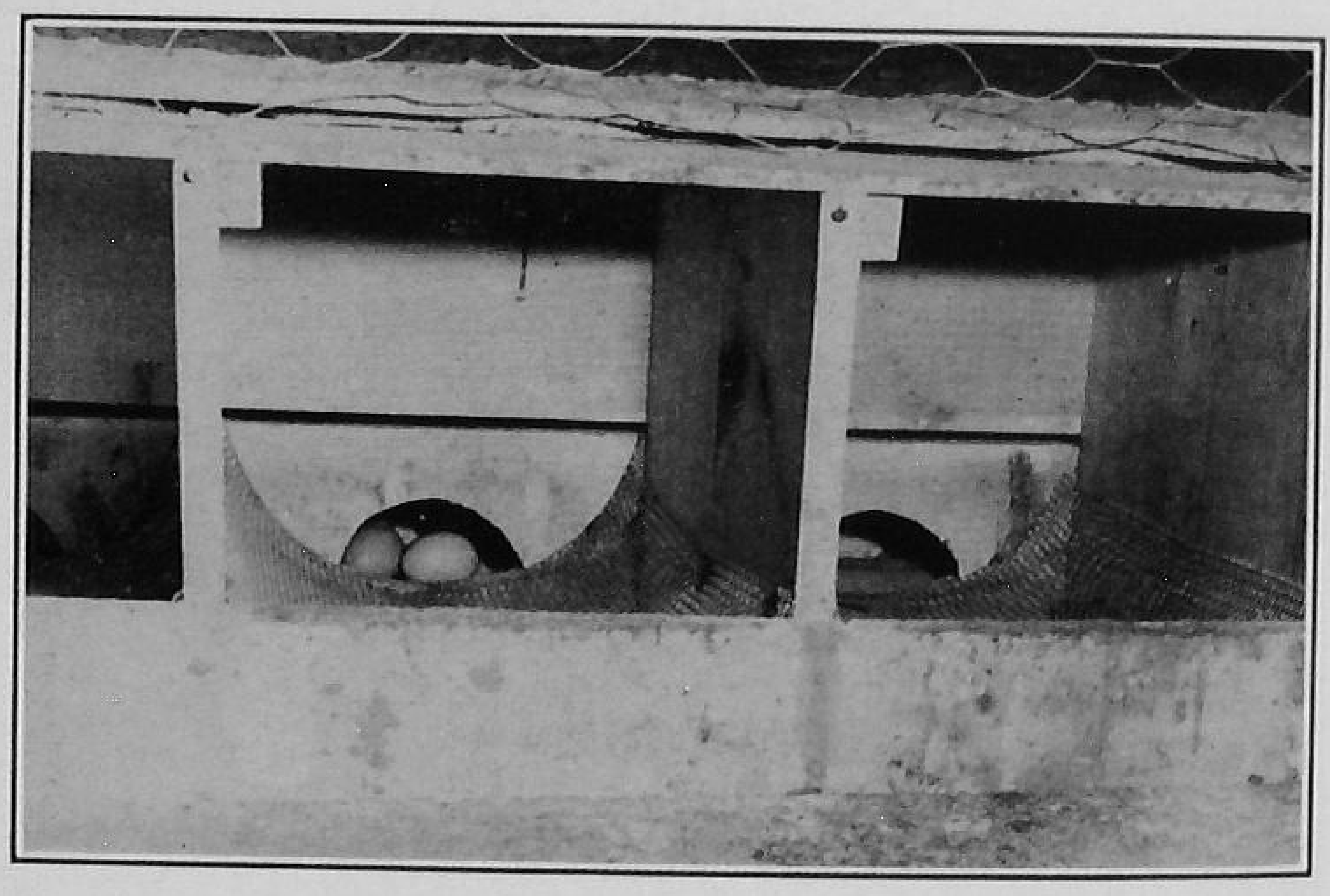


FIG. 214.—Eggs roll gently out of this wire-floor nest onto a belt which serves two rows of nests back to back. Each nest is 12 × 18 inches. See Figure 215 for a view of the automatic egg gatherer. (*Photograph by Eleanor Gilman.*)

The difference between the value of a pullet at the beginning of the year, and the value of the same individual at the end of the year, is depreciation, and is one of the important costs in commercial egg production. If a pullet is worth $2.50 at the beginning of the year, and will bring but $1.25 after twelve months of laying, it has clearly cost the poultryman $1.25 just to own her for a year, without considering any expense for feed, labor, housing, interest, and the like. The only way he could have avoided this cost is to have raised the pullet at a maximum cost of $1.25 which would mean no profit on the pullet-rearing operation as well as a decision to keep the pullet for laying purposes rather than to sell her at $2.50. Whether one likes it or not, depreciation is just as

much a part of the cost of producing eggs as it is a part of the c
of owning an automobile.

In cost accounting work, depreciation is usually determined adding together the value of layers at the beginning inventory, t value of any pullets raised and later added to the laying flock, a the value of any pullets purchased, and subtracting from this to the sum of the ending inventory and the value of any layers s or eaten. With equal death losses, depreciation is higher in Legho flocks than in flocks of heavy breeds because of the greater me value of the latter. For the same reason, death losses are m serious, as measured in dollars, in flocks of heavy breeds.

Price of Market Eggs.—Although price is less completely un the control of the farm operator than the other factors that ha been discussed, it is nevertheless true that the average price ceived for eggs is one of the most important factors in determini the labor income on a poultry farm. A high average price is t result of securing a large proportion of the yearly egg producti during the high-price months, or of marketing eggs at premi prices, or both. The effect of egg price on labor income is clea shown by the data of Table 65. Misner, in discussing poul farming in New York State, has pointed out the importance price received for eggs in the following words, "If one can obtai premium of 1 cent per dozen of eggs, and save 1 cent a dozen buying feed at a saving of $3 per ton, the difference of 2 cents dozen on 12.5 dozens of eggs per bird annually would be 25 ce per hen per year, or about $500 on 2000 birds. Poultrymen sho go after a price premium, and such arrangements as will permit go after a price premium, and such arrangements as will permit saving on feed."

TABLE 65.—THE RELATION OF PRICE RECEIVED FOR EGGS TO LABOR INCOME OTHER FACTORS ON 108 NEW YORK STATE POULTRY FARMS IN 1931. (DATA MISNER, 1932.)

	Value of eggs per dozen		
	Less than 27 cents	27 to 31 cents	31 cents or more
Number of farms	38	37	33
Value of eggs per dozen	25c	29c	35c
Dozens of eggs per man	8,434	8,746	9,106
Dozens of eggs produced	14,463	15,751	21,555
Cost of eggs per dozen	29c	30c	36c
Labor income	$500	$946	$1,827

When To Dispose of Layers.—Because of the seasonal variation egg prices, poultrymen sometimes sell an entire flock after a sha break in early spring egg prices instead of carrying the lay through an entire year of production. A comparison of all-pul flocks in New York State in 1946–47, in which the beginning num of layers was about 1000, showed a profit of 0.9 cent a dozen 16 flocks kept the entire year, in contrast to an average loss of ... sold out during the year.

TABLE 66.—CUMULATIVE EGG INCOME AND CUMULATIVE COSTS PER LAYER FOR A 200-EGG FLOCK STARTED IN OCTOBER

Month	*Eggs per pullet*	*Feed per pullet (pounds)*	*Feed cost @ 4½ cents a pound*	*Other costs*	*Total cost*	*Value of eggs*	*Margin*
October	14	8.4	$.38	$1.72	$2.10	$.59	—
November	29	16.9	.76	1.84	2.60	1.22	—
December	45	25.6	1.15	1.96	3.11	1.86	—
January	62	34.4	1.55	2.08	3.63	2.55	—
February	79	43.2	1.94	2.20	4.14	3.23	—
March	99	52.6	2.37	2.32	4.69	4.08	—
April	118	61.7	2.78	2.44	5.22	4.91	—
May	137	70.8	3.18	2.56	5.74	5.73	—
June	155	79.8	3.59	2.68	6.27	6.57	.30
July	171	88.5	3.98	2.80	6.78	7.31	.53
August	186	97.1	4.37	2.92	7.29	8.01	.72
September	200	105.3	4.74	3.04	7.78	8.60	.82

NOTE: Eggs per pullet based on the Connecticut "standard" for 200-egg flocks. Feed per pullet calculated from the formula $F = 25 + 8W + E/7$, reduced to a monthly basis (for 5½-pound hens this becomes $F = 5.75 + E/7$), increased by 8% to allow for the feed eaten by the 16% of layers which die. Other costs calculated as $1.60 per layer plus 12¢ per layer per month for labor. Egg values calculated as weighted average price per dozen for brown eggs according to seasonal prices and size distribution given in Cornell Agr. Exp. Sta. Bulletin 865.

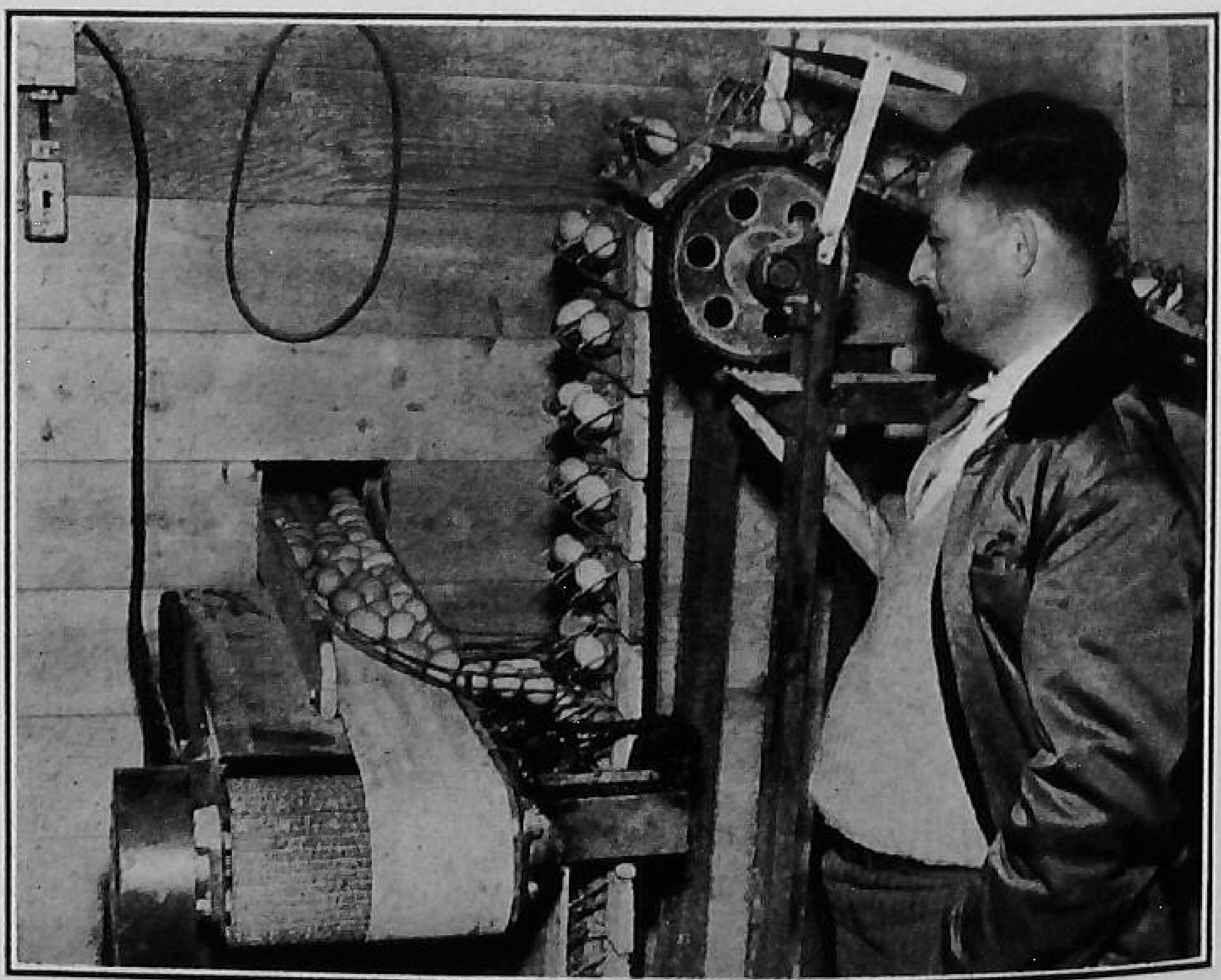


FIG. 215.—Eggs from three floors are gathered by conveyor belts moving at six feet a minute. Picture shows how eggs are picked up by the vertical conveyor and taken to the grader on the second floor. Coll's Poultry Farm, East Jaffrey, N. H. (*Photograph by Eleanor Gilman.*)

Since there are many fixed costs which must be charged against the flock whether it is kept seven months or twelve, and since it takes several months of production to build up receipts to the point where they exceed accumulated costs, it is not likely that early selling of an entire flock will often prove profitable. The data in Table 66 have been compiled to show how costs and egg income accumulate from month to month when the average yearly egg production is 200. For a flock started about October first, accumulated egg income does not amount to as much as accumulated costs until about the first of June. Any profit must therefore be made from eggs laid after June first.

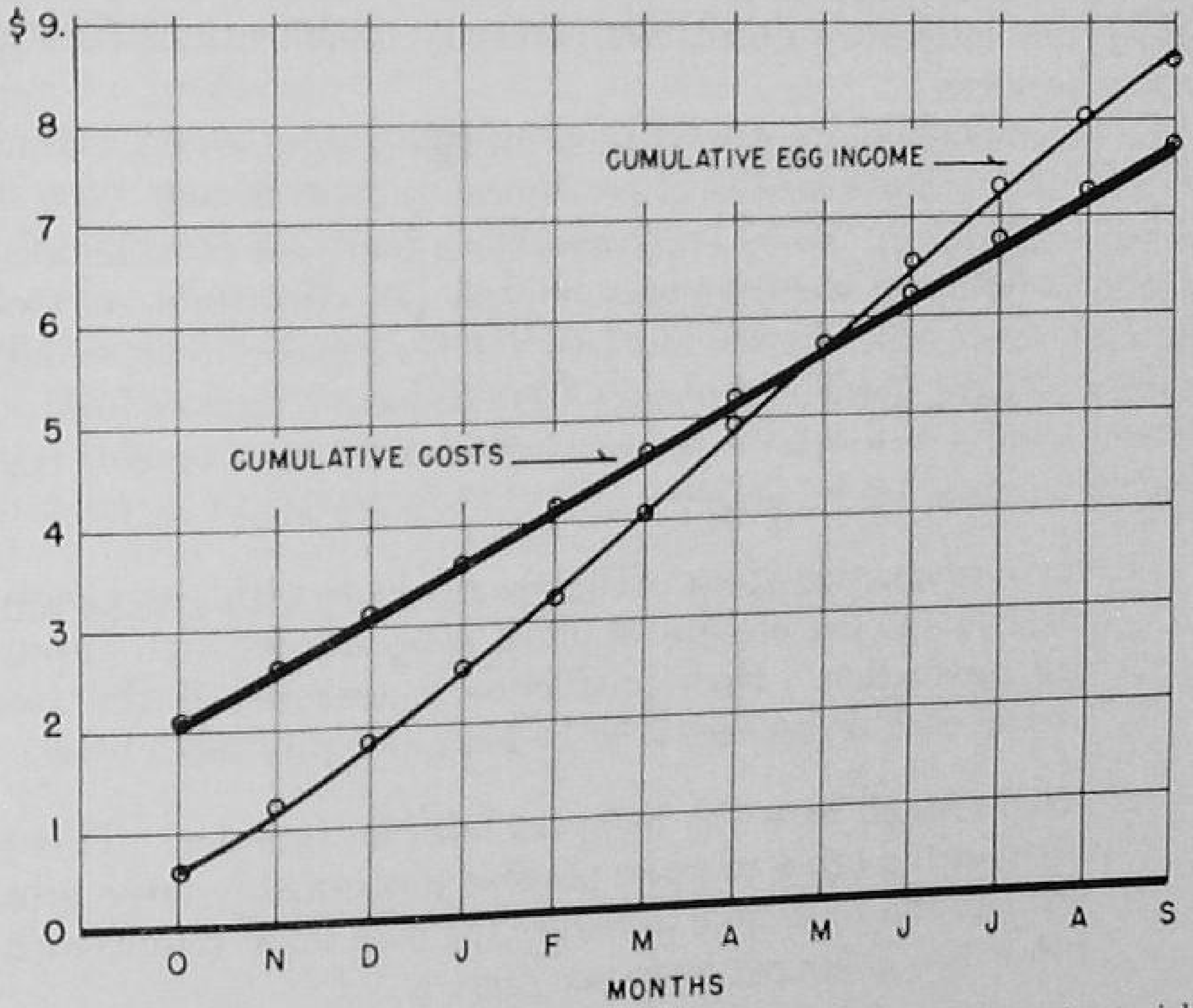


FIG. 216.—When a pullet flock starts laying in October, it takes about eight months for cumulative egg income to catch up with cumulative costs. (See Table 66.)

Poultry Farm Organization.—Perhaps the most significant, and at the same time the most encouraging fact growing out of the various analyses that have been made of poultry farm records is that whether the labor income is high or low depends almost exclusively on the operator himself. The possibilities seem to be limited only by the extent to which he will adopt profitable practices and a profitable farm organization. As Scudder and co-workers put it, "If so large a group as 19 per cent of all the flocks (441) for the three-year period return, each year, $2 per hen in payment for the operator's labor, surely this is not a result of any accident or good luck. It must be and is due to more efficient operation, resulting in lower cost of production and a wider margin of profit."

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